Weapons of Choice I

NIWC Pacific

Weapons of Choice

A History of the Point Loma Navy Laboratory

Volume I

Naval Information Warfare Center Pacific

WEAPONS OF CHOICE

A History of the Point Loma Navy Laboratory

Volume I

NAVAL INFORMATION WARFARE CENTER PACIFIC

Contents

Appendixes

Figures

Photo Credits

All figures are official U.S. Navy photographs, with the following exceptions and acknowledgments:

Photos courtesy of the Naval History and Heritage Command, appear on **Pages 10** NH 43580, **12** NH 69986, **19**, **56** NH 63092, **129** NH 91346, **192** NH 72792, **236** USN 1117395, **450** NH 78294, **561** NH 65031.

Photos courtesy of the National Archives, appear on **Pages 56** 80-G-703837, **69** 80-G-21666 and 80-G-238298, **75** 80-G-166187, **394** USN 1063729, **225** 80-G-384001.

Photos courtesy of Naval Air Warfare Center Weapons Division appear on Pages 23, 138, 152, 154, 161, 170, 172, 177, 204, 210, 216, 285, 292, 296.

Photos courtesy of Special Collections and Archives, UC San Diego appear on pages 119, 195, 281.

Photos courtesy of the Archives, California Institute of Technology appear on Pages 21, 41.

Photo Harvard University, Cruft Laboratory Photographic Dept., courtesy AIP Sergé Visual Archives appear on page 47.

Photo courtesy of the Niels Bohr Library and Archives appear on page 48

Photo of Dr. Howard Wilcox on Page 442 courtesy of his son, Brian Wilcox

We thank the organizations and individuals who provided us photographs and allowed us to use them for this publication.

Foreword

The Navy historically has exploited new technologies to improve its warfighting systems. Among the early initiatives were the robust laboratory developments in San Diego, long a focus of naval operations in the Pacific. Close to the fleet and exceptional academic resources, the laboratories were able to focus on naval needs and develop advanced solutions. Over the years, their advanced technologies greatly improved the capabilities of the U.S. Navy.

These advanced technology laboratories were founded in the days when shipboard computers were marvelous mechanical devices filled with cams, rotors, and levers to do precise numerical calculations for specific functions. The electronic systems were radios filled with giant vacuum tubes generating lots of heat. As World War II unfolded, electronic systems were just being developed to aid in increasing accuracy of guns to engage attacking aircraft. This volume chronicles the Navy's initiatives to capitalize on new capabilities that electronics could bring to the fleets to dramatically increase effectiveness and power projection.

Appropriately co-located atop Point Loma with the Navy Radio Station that provided communications to Navy ships dispersed around the world, the Navy Radio and Sound Lab was founded to develop new electronic components to outfit the ships with increasingly advanced systems for improved warfighting execution. New communications systems interconnected the fleets, improved systems were developed to enhance the command and control over forces, and better methods to capture intelligence of enemy intentions were conceived and proven by the lab to expand the fleet's backbone for mission success.

Later, the Naval Electronics Laboratory Center, the renamed Radio and Sound Lab, handed off its piers and platforms on the Point Loma bayside waterfront to the new Naval Undersea Center to enhance the Navy's need for robust anti-submarine detection, tracking, and weapons capabilities.

Over time, naval operations became more integrated and intertwined. It became apparent that the foundations of the developments and systems at the two Point Loma organizations were so complementary that integrating the two organizations provided a more solid foundation for evaluating technologies and implementing them into seagoing capabilities. Naval

Electronics Laboratory Center and Naval Undersea Center were merged into the Naval Ocean Systems Center (NOSC) to strengthen the technical integration of the labs to provide even more significant capabilities to the fleets.

This treatise provides the details of these organizations and the systems they developed over the years and the people who led the way in achieving such outstanding results. Today, the now called Naval Information Warfare Center Pacific continues to build astonishing capabilities for the Navy to maintain its leadership in the Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance domains.

Naval Information Warfare Center Pacific has done an excellent job chronicling the early history of its predecessor organizations. This document's development was overseen and edited by Tom LaPuzza, an employee there for 50 years. He is intimately knowledgeable of the thrusts of the laboratory and the people who created its history over the years. He was the Public Affairs Officer of the Systems Center during my tenure from 1995 to 1998 as commander of the parent organization, Space and Naval Warfare Systems Command. I worked often with him during that period. He always crafted insightful materials, be it publication for the people of the organization or large technical events for defense-related organizations to see and understand the technologies being fielded.

This volume traces the history of the organizations from pre-World War II to 1977. Written more like a novel than a technical document, it lays out the history of the foundation elements of the present Warfare Center during the first half of its existence, how it evolved, the impetus for changes along the way, and the significant developments achieved.

George F.A. Wagner
Rear Admiral, U.S. Navy (Ret.)
Former Commander, Space and
Naval Warfare Systems Command

Preface

I don't recall the first time I visited Point Loma. It is probable it was during one of my Omaha family's visits to my San Diego grandparents. Whenever it was in the late 1950s/early 1960s, we would have been driving to see Cabrillo National Monument, with no idea there was a Navy laboratory out there that would play an essential role in my future.

I do recall my first day working for that Navy laboratory was Thursday, October 23, 1969. I was stationed at the lab's facility in Pasadena for a couple of years, commuting to the San Diego headquarters at the south end of Rosecrans Street on Point Loma every month or so until I moved permanently in the spring of 1972. I worked for a handful of years at the lab's Bayside location, then moved in 1977 up the hill to the Topside complex just east of Cabrillo Memorial Drive. I also recall that specific date, February 28, the day before the March 1 establishment of the Naval Ocean Systems Center, resulting from my organization, the Naval Undersea Center, consolidating with the Naval Electronics Laboratory Center. Since then, through four more name changes, I've been a full-time employee, a re-employed annuitant, and an emeritus. In actuality, I am a retiree, but I don't consider myself one, and probably won't until someone in authority tells me I can't get through the security gate any more. At the end of a speech I made back in 2006 at an awards ceremony, I said, very sincerely, "Thank you, so much, for letting me work here."

Over the years, then decades, I found myself deeply gratified that I was blessed with the opportunity to work with the amazing people described in the following pages, many of them world-class scientists and engineers in their chosen fields. Substantial numbers of the rest were college graduates highly sought after for their academic excellence, many of whom told me in interviews that the salary offered by the Navy was one of the lowest, if not the lowest, they received. And yet, they elected to take a lower salary because they saw some perhaps indefinable benefit in working for the Navy laboratory over a much better-paying opportunity elsewhere. For much of my career at the lab, as the newspaper editor and the public affairs officer, my major task was to publicize their achievements, and, given those achievements, I found it a remarkably easy task.

Developing the first of what is presently planned as a two-volume history of the lab's first eighty years of accomplishment has been less easy, but no less fun. Initially I was fairly optimistic that professional "outsiders" with reasonable credentials could write this history, and my responsibility would be merely to polish it for publication. Several "insiders," whose opinions I value highly, suggested that was an unlikely possibility: the number of years, the number of people, the diversity of projects, the complexity of the issues and politics involved in the formation and development of what is today Naval Information Warfare Center Pacific severely limited a credible understanding by someone who had not been part of that organization for decades.

In the end, the insiders were right. My vision of the Center's history differed substantially from the product received, such that my planned limited revision would not have achieved it. With substantial assistance from associates, who are mentioned below, I basically started over to move the project forward. Ultimately, I can take credit for a substantial amount of what is presented here; however, with the wisdom gained after years of effort, I realize how many bakers it took to make this cake.

I congratulate and thank Carmela Keeney, who was the Center's Executive Director at the time, for funding the original contract for this work and for staying the course with me through nearly a decade of effort, including a substantive first review of the somewhat completed project. Also in that category of "from the beginning" is my one-time office mate and continuing friend who set up that first contract and monitored it on behalf of the Navy, Ann Dakis. And rounding out that category, special thanks to my wife Donna, the one most impacted by the days and months and years I spent on this project.

I owe substantial gratitude to Cliff Lawson, an outstanding historian who authored Volumes 4 and 5 of the history of the Navy organization at China Lake. Viewing a somewhat final draft of Volume 4 prompted me to propose this history in the first place, and Cliff served as a wonderful mentor in responding to scores of early and late questions about how we would develop our own history, with insightful and invaluable responses, often pages long, while involved in his own writing efforts on those two volumes.

Scores of technical folks provided me valuable interviews to supplement the technical publications, official documents, in-house newspapers, and various Center histories with first-hand project detail augmented with personal insights that added an essential human touch to impersonal technology development.

I contacted many former and current employees on single or multiple questions to fill in gaps in my knowledge. Several were called upon numerous times but still maintained patience with me, and I am most grateful to them. Outstanding among those were Augie Troncale, Morris Akers, Norm Estabrook, Mort Heinrich, Homer O. (Hop) Porter, and Bob Watts.

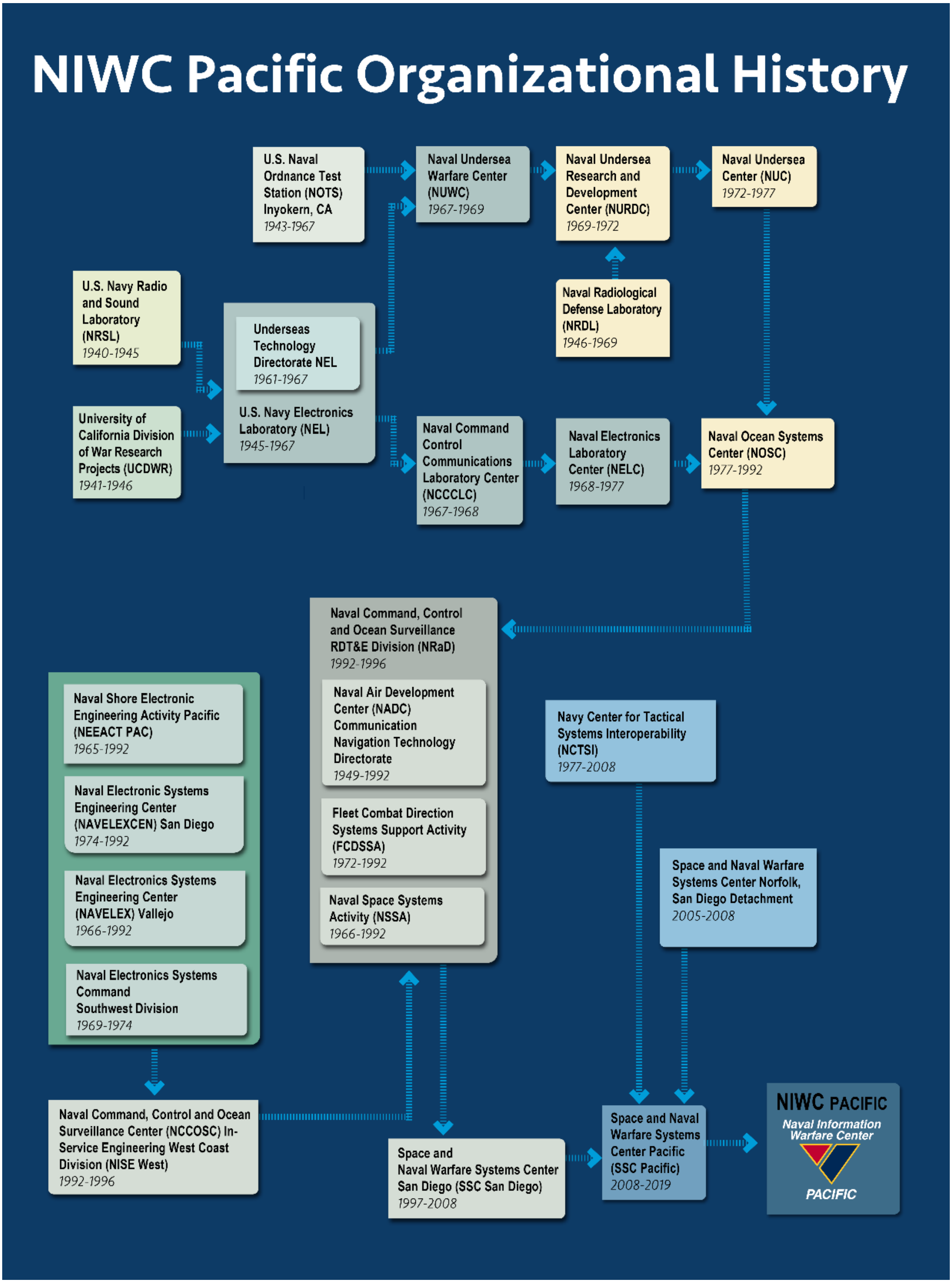
The history I envisioned required a substantial amount of original research of the organization, particularly its very early years. My undertaking of that effort with limited experience was perhaps unwise. For the entirety of this project, however, the Center's technical library staff provided significant expertise to counter that limitation. The continuous support of Center librarian and archivist Kelly McKeever and relentless researcher Linnett Von Husen, often daily, usually weekly, always monthly, year after year, was truly extraordinary. In a genuine team effort, we were able to locate documents hidden by time in the library's vault and elsewhere that contributed immeasurably to the content of this work.

When the initial writing was completed, the review efforts of Carmela Keeney and Dr. Stephen Russell, the editing skills of Lynn McDaniel, and the lay-out expertise of Bob Price, with assistance from Kelly McKeever, completed the project.

Acknowledging the essential contributions of those mentioned and numerous others who provided a little or a lot, I acknowledge as well my sole responsibility for errors, omissions, and misrepresentations that appear in these pages.

My thanks to all those mentioned above and many others for their dedicated contributions to this project. And my special thanks to the men and women of the Naval Information Warfare Center Pacific and all its predecessors for providing a story worth telling.

Tom LaPuzza



NIWC Pacific Organizational History
U.S. Naval Ordnance Test Station (NOTS) Inyokern, CA 1943-1967
Naval Undersea Warfare Center (NUWC) 1967-1969
Naval Undersea Research and Development Center (NURDC) 1969-1972
Naval Undersea Center (NUC) 1972-1977
U.S. Navy Radio and Sound Laboratory (NRSL) 1940-1945
Underseas Technology Directorate NEL 1961-1967
U.S. Navy Electronics Laboratory (NEL) 1945-1967
Naval Radiological Defense Laboratory (NRDL) 1946-1969
University of California Division of War Research Projects (UCDWR) 1941-1946
Naval Command Control Communications Laboratory Center (NCCCLC) 1967-1968
Naval Electronics Laboratory Center (NELC) 1968-1977
Naval Ocean Systems Center (NOSC) 1977-1992
Naval Command, Control and Ocean Surveillance RDT&E Division (NRaD) 1992-1996
Naval Air Development Center (NADC) Communication Navigation Technology Directorate 1949-1992
Fleet Combat Direction Systems Support Activity (FCDSSA) 1972-1992
Naval Space Systems Activity (NSSA) 1966-1992
Naval Shore Electronic Engineering Activity Pacific (NEEACT PAC) 1965-1992
Naval Electronic Systems Engineering Center (NAVELEXCEN) San Diego 1974-1992
Naval Electronics Systems Engineering Center (NAVELEX) Vallejo 1966-1992
Naval Electronics Systems Command Southwest Division 1969-1974
Navy Center for Tactical Systems Interoperability (NCTSI) 1977-2008
Space and Naval Warfare Systems Center Norfolk, San Diego Detachment 2005-2008
Naval Command, Control and Ocean Surveillance Center (NCCOSC) In-Service Engineering West Coast Division (NISE West) 1992-1996
Space and Naval Warfare Systems Center San Diego (SSC San Diego) 1997-2008
Space and Naval Warfare Systems Center Pacific (SSC Pacific) 2008-2019
NIWC PACIFIC
Naval Information Warfare Center
PACIFIC

Introduction

The so-called “silent deep” is not silent at all. The ocean crackles, pops, moans, and roars like a full-on forest fire. If you are aboard a ship, listening for the soft thrumming of a submarine screw as the deadly boat approaches, you have a problem. If you are on that submarine, straining to interpret sonar signals through the cacophony, maneuvering all but blind through enemy waters that might be heavily mined, you have a different problem. At the outset of World War II, the U.S. Navy had both problems at the same time. It would call on American scientists and engineers to solve them.

This is the story of a Navy laboratory in San Diego, California, that employed a fair number of those scientists and engineers. Its complex but impressive organizational history began shortly before the Second World War, and to a substantial degree involved those submarines.

Today’s Naval Information Warfare Center Pacific traces its origins to those pre- and early World War II days, when the Navy was evaluating its responsibility to defend the nation and finding the results of that evaluation troubling. Beginning with a handful each of military and civilian personnel, the Navy’s first West Coast laboratory, the forerunner of the information warfare center, was charged with developing electronic technology and matching it to the service’s increasingly complex communication needs.

Shortly, however, as the country was formally embroiled in far-ranging conflict, the submarine threat forced the fledgling organization to focus much of its attention in that direction. Fortunately, the nation’s universities, understanding the approaching storm, had stepped forward in large numbers, seeking to be of service. Our story, at the outset, involves several of those universities, whose professors provided technical expertise desperately needed by the military to overcome deficiencies in the capabilities required to face the growing threat from across the Atlantic.

As the war progressed, additional requirements surfaced for new-technology weapons delivered from aircraft, resulting in establishment of another Navy laboratory that is also an essential element of our story. Like the communications/electronics organization, this second lab, which developed and tested weaponry, also had its early history closely intertwined with a major California university.

Over succeeding decades, those two organizations grew, merged, gained and lost important personnel, consolidated, but almost always continued to increase in size and significance, in numbers of people and funding and sponsors and projects. Eventually the two Navy laboratories became one, although continuing to change and evolve until it became, at the time of this writing near the end of the second decade of the twenty-first century, Naval Information Warfare Center Pacific.

To report adequately on the sheer enormity and complexity of the organization, we elected to devote two volumes to this history. This first volume relates to those two initial organizations as they functioned almost entirely independently of one another, with an occasional supporting hand lent to one another in a specific area of expertise. The second volume will continue the story as the two fairly disparate organizations were merged, based more on financial considerations than mission-oriented ones, and as management labored to consolidate them in a manner rendering them efficient and effective. And succeeded. Since change is inevitable, it would continue for the Point Loma Navy laboratory, as people and projects and missions were added and pulled away.

As the millennium approached and passed, speakers would tell important visitors the organization was managing nearly a thousand projects. Clearly, our story cannot adequately cover all of those, so we had to choose selectively to provide the flavor of what was accomplished rather than relishing every morsel of it. Essential to acknowledge is the fact that many of those projects were performed for U.S. military and other organizations whose operations required secrecy; the very existence of some of those entities is a closely held secret. As a result, large numbers of significant projects involving brilliant work by the Center's innovative technologists will never appear in a story like this.

As will be better understood as it unfolds, this is a story of cooperation (and occasionally lack of it) between military and civilian personnel, the former at nearly all levels of enlisted and officer ranks, the latter principally technical personnel with requisite wisdom to solve some of the most complex problems ever faced by the Navy and the Nation. It is a story of technology invention and development, often with the urgency of war-time requirements, always with the significant criticality of military needs, usually with the required reality of insufficient dollars to develop everything that the technologist dreamed and the sailor desired.

A military enterprise by its very nature involves weapons by which one entity—tribe, city-state, country, superpower—seeks to conquer and rule over another, and by which the latter seeks to defend against that possibility: fists, slingshots, swords, bows and arrows, guns, rockets, bombs, lasers, germs. The list is seemingly endless, and a military laboratory by *its* nature usually is charged with developing more and better of those weapons. Our story involves a number of such devices, but eventually will focus on that most critical of commodities and most formidable of weapons—information. For with few exceptions, weapons succeed or fail based on where and when they are positioned in relation to the enemy and his weapons, and only timely information (or blind luck) can affect that.

This is a story of complex technical thinking, undreamed of hardware and machinery, concepts developed to death or dying before they reached any sort of existence. It contains tales of exotic locations, and some places better forgotten; of laboratories that were the stuff of science fiction before and science achievement after; of false starts and dead ends and victories grasped almost miraculously from the jaws of funding shortages.

It will discuss technologies covering a staggering range of disciplines and military warfare areas, including atmospheric propagation and underwater acoustics, communications in all frequency bands and all arenas important to the Navy from space to the bottom of the sea, information collection and dissemination, microelectronics, environmental sciences, marine mammal research and operational use, weapons launched from every imaginable platform, navigation and meteorology, intelligence, signal processing, robotics, and undersea vehicles.

In the very early years of today's Naval Information Warfare Center Pacific, the threat to America loomed like a vast storm approaching off the ocean. In the years that followed, America's senses of strength and vulnerability waxed and waned, but its position as the world's preeminent military power remained, and remains, intact. This is in no small part due to the brilliance and dedication of those who worked at the Navy laboratory that began, and remains, on the Point Loma peninsula in San Diego.

In the end, this is the story of a large number of very smart people who put aside dinners at six and family vacations to ensure the men and women of the United States Navy particularly and the other services as well had the technology to execute the missions given them, and to live to tell about it.

The Point Loma peninsula on the extreme southwestern corner of the U.S. has been home to one of the Navy's foremost laboratories for eight decades.

1

Beginnings

In May of 1941, a slender, soft-spoken physicist named Waldo K. Lyon arrived at the U.S. Navy Radio and Sound Laboratory on Point Loma in San Diego. The ink was not yet dry on the certificate for his Ph.D. from the University of California at Los Angeles. He had completed the final months of his doctoral work under a deferment supported by the university after his very low draft number resulted in his being called up for military duty the previous December. In San Diego, he joined Leo P. Delsasso, one of his UCLA physics instructors who was also a naval reservist. Lieutenant Delsasso had served on active duty in World War I, remained in the reserves while he attended college and pursued a research and teaching career, and requested a leave of absence from the university in January 1941 to serve again in uniform at the seven-month-old Navy Radio and Sound Lab.

It was at the invitation and behest of his former instructor that Waldo Lyon arrived on Point Loma. Lyon was not an obvious choice for the laboratory, if his area of study and dissertation were any indications. He had done all his undergraduate and graduate work in optics and infrared spectroscopy, neither of which was pursued at the radio and sound lab at the time. Lieutenant Delsasso must have seen something extraordinary in the twenty-six-year-old scientist, however, because he was put to work immediately on the laboratory's most critical areas of work: acoustics, electronics, and related technological research centered on submarine warfare.

The naval officer would complete his tour shortly after the conclusion of the war and return to the classroom and research laboratory. The new doctor of physics would spend the next half century and then some working on Point Loma, his career taking an unexpected turn within a few years.

That turn would place him in a position of technological prominence for the future war that might have been anticipated by a sharp strategist critically examining events leading up to and immediately following Victory in Europe Day.

"The two words 'communication' and 'information' are often used interchangeably, but they signify quite different things. Information is giving out; communication is getting through," according to Chicago newspaper columnist Sydney J. Harris. Communication—the passing of meaningful information from one person to another, from a company to its employees, from a military commander to the people and platforms under his or her command—is the lifeblood of a relationship, a corporate strategy, mission execution. Without communication, without a means to pass emotions, principles, and orders, relationships end, businesses fail, enemies triumph.

This is a history based substantially on the communication requirements of the United States Navy: internal and external, over land and sea, in space and under the oceans, between and among the wide array of platforms and people the Navy employs to fulfill its mission of guarding the safety and security of the United States of America. Because the vast majority of communication involves technology of one type or another, a technology developer is required to design, build, refine, and improve it. For the past eight decades, the critical mass of the Navy's technology related to communication, plus that in areas closely related and substantially unrelated, has been developed by an organization called, from the late 2010s to the early 2020s, Naval Information Warfare Center Pacific.[1]

Today's Naval Information Warfare Center Pacific is and has been one of the Navy's premier laboratories since World War II. Its history, fairly typical of the service's labs, is complex and convoluted: numerous changes in title, mission, and organizational structure over those decades were driven by higher-level directives, over which it had no control and to which it often lacked even minimal input. The one constant has been the

---

[1] As will be related in detail throughout the two volumes of this history, and as is illustrated by the accompanying wiring diagram, the organization's title has changed a fair number of times, reflecting changes in mission, mergers and reorganizations, and changes in headquarters agencies. Given that history, it is not unreasonable to imagine another name change even before the publication of this history.

responsibility, and the credible fulfillment of that responsibility, to develop new technology to support the Navy, the other services, and assorted other government entities.

The elemental building blocks of that organization were the Navy's first two laboratories on the West Coast—the U.S. Navy Radio and Sound Laboratory and the U.S. Naval Ordnance Test Station, and the two universities that substantially supported them in their earliest days—the University of California and the California Institute of Technology. The two universities supplemented their designated roles of teaching students for the several years of World War II with technology development support of the two Navy labs, and then returned to their traditional responsibilities. Unlike many of the military organizations that came into existence with the same stimulus of that war and then disappeared with the cessation of hostilities, the two laboratories not only continued, but grew and prospered after the conflict. We will relate the story of those early days of laboratory-university cooperation, and the much more detailed stories of those Navy laboratories in the ensuing decades, in this history. Before we launch upon the waters of establishment, however, it is reasonable and in fact necessary to reach back further in the history of Navy technology development.

THE NAVY LABORATORIES

On August 31, 1842, the Congress approved legislation establishing five organizations to provide critical elements for the U.S. Navy, dividing the service's material readiness requirements among bureaus for yards and docks; construction, equipment and repairs; provisions and clothing; ordnance and hydrography; and medicine and surgery. For the next century and more, the bureau system provided for the material and procurement needs of the Navy, with various numbers and reorganizations of bureaus as the service's requirements changed and technology advanced. Although the actual advancement of technology was generally outside the purview of the bureaus, there were early instances of Navy involvement in applying commercial technical developments and even initiating some of its own to meet its needs. Those initial self-help efforts would mature, some decades later, into the Navy laboratories, several of which this history will discuss in detail.

The earliest of the forerunners of today's Navy laboratories was the Naval Torpedo Station, founded in 1869. According to a study researched by retired Navy Commander Robert L. Sminkey, the station was established at Goat Island in the harbor of Newport, Rhode Island, "as a Navy experimental station for the development of torpedoes and torpedo equipment, explosives, and electrical equipment." He went on to qualify that statement:

> Actual torpedo development in the United States during the period 1870-1900 consisted principally of experimenting with various existing types. Chemical, electrical, and rocket propulsion was attempted, and guidance and new power generation systems were developed. Torpedo Station personnel conducted many experiments and tests of the devices submitted by civilian and military scientists and engineers.[2]

Similar early Navy efforts in technology advancement focused on testing and engineering, some production and more acquisition, rather than research and development, and originated in the nation's capital at the Navy's first shore establishment:

> … the BuOrd [Bureau of Ordnance] activities at Dahlgren and Indian Head and the BuShips [Bureau of Ships] activity at Carderock all have their origins at the Washington Navy Yard, and were primarily testing or production facilities.[3]

Naval communications

While the Navy pursued some technology development of its own, most notably in weapons and electrical equipment, it chose not to involve itself directly in communications advancements: "Early Navy radio equipment was developed by commercial companies under Navy sponsorship, since the Navy did not possess a suitable in-house capability."[4]

Despite its obvious importance and value to far-flung fleets operating on the world's vast oceans, technology advances were a long time coming

---

[2] Robert Loys Sminkey, Naval Torpedo Station, Newport Rhode Island.
[3] Robert V. Gates, "History of the Navy Laboratory System," *International Journal of Naval History*, April 2016, 1.
[4] Louis A. Gebhard, *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (Washington, D.C.: Naval Research Laboratory, 1979), 15.

for communications at sea. For centuries, such communications were limited to what a sailor on a ship could see or hear. At the height of the sailing age, nineteenth-century warships communicated via flags, semaphore, and codes sent via signal lamp—or, if close enough, calling through a megaphone.

Naval communication evolved slowly but progressively through the next century, improving particularly with the creation of simple codes such as Morse, but in the era of Theodore Roosevelt's Great White Fleet the Navy was still signaling with flags and signal lamps, and even experimenting with homing pigeons as a method of communicating ship-to-shore.[5]

The setting of the nineteenth and dawn of the twentieth century saw revolutionary technology changes in major categories of naval warfare, including rapid advances in ship-to-shore, ship-to-ship, and underwater communications. In 1899, the first official Navy message to travel over "wireless telegraphy" was sent from the steamship *Ponce* to Highland Station on the New Jersey coast by a twenty-five-year-old Italian inventor and electrical engineer named Guglielmo Marconi.[6]

Marconi had already demonstrated the efficacy of his radio to the British Navy, and the implications of instant communication over long distances were immediately obvious. On December 1, 1899, the Chief of the U.S. Navy's Bureau of Equipment wrote the Secretary of the Navy, recommending use of the Marconi system and purchase of twenty radio sets, with cost figures that included an annual royalty fee. Within a few days, when it became obvious Marconi's stipulation of the royalty fee constituted a fairly high price (and possibly illegal purchase without funds obligated for that purpose), the bureau chief sought outright purchase, which Marconi declined.[7]

In the long run, the Navy took another tack:

---

[5] Captain Linwood S. Howeth, USN (Retired), *History of Communications-Electronics in the United States Navy* (Washington, D.C.: U.S. Government Printing Office, 1963), 11.
[6] *Proceedings of the United States Naval Institute*, Volume 28, Issues 1-2, 450. Also *History of Communications-Electronics in the United States Navy*, 27.
[7] *History of Communications-Electronics in the United States Navy*, 35.

> After rejecting the monopolistic tenders of the Marconi interests, the Navy decided to study the situation carefully, prior to making a decision, believing that a policy of watchful waiting would prove more beneficial in the long run and that the time lost would be regained by the eventual acquisition of improved equipment. Two years were spent in this manner.[8]

During that time, in his annual report of 1901, the Secretary of the Navy advised of the plan to study various wireless telegraphy equipment that had been offered by American and European countries, including Marconi's. That effort focused on recalling a naval officer to active duty, sending him to Europe to study the offerings, and dispatching a junior officer and two enlisted personnel to join him. The plan was for the trio to undergo training in the use of the equipment by some of the offering companies.[9]

Following those efforts, the Navy purchased wireless equipment from four companies to evaluate operation of that equipment on its own ships.

In the summer of 1903, initial installations of wireless equipment were completed on eight ships prior to a major fleet exercise in the Atlantic—USS *Illinois, Kearsarge, Maine, Olympia, Baltimore, Texas, Prairie,* and *Topeka*. (The latter two ships had participated in initial ship-to-shore testing the previous year.)[10] The results of the exercise convinced a number of senior Navy officers that wireless could be a substantial asset to the service.

Roosevelt assigns Navy radio use

In 1904, President Theodore Roosevelt assigned a large portion of the government's radio use to the Navy, and by year's end, thirty-three ships and eighteen shore stations were outfitted with radios.[11] One of the latter

---

8 *History of Communications-Electronics,* 37.
9 *History of Communications-Electronics,* 40-46.
10 *History of Communications-Electronics,* 53-54.
11 *Chronological History of U.S. Naval Communications*. Originally published in 1958 by the U.S. Navy as a complimentary document for attendees of the 10th American Radio Relay League National Amateur Radio Convention in Washington, D.C. It dated Roosevelt's assignment of U.S. Government radio responsibilities to the Navy as 1904. A subsequent edition, generally identical to the first document but undated with entries up to 2006, gave both dates as 1906. An entry in Howeth, *History of Communications-Electronics*…, 117, cites a document by a flag officer instructed personally by Roosevelt

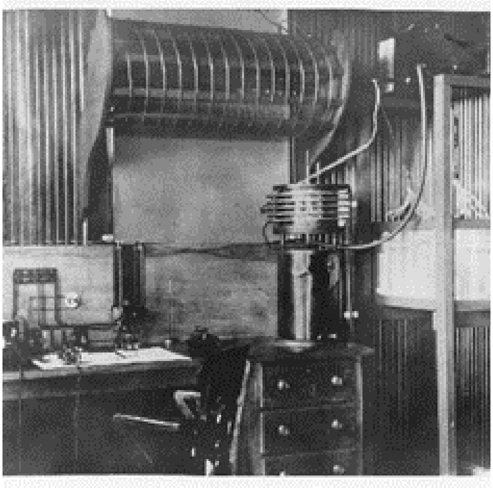
was the Navy Radio Station Point Loma, built as part of a Pacific coast chain of wireless stations from Mexico to Canada, and occupying property on the top of the Point Loma peninsula on the southwestern edge of San Diego, California. Even before it was formally commissioned, the station forwarded radio traffic concerning the San Francisco earthquake on April 18, 1906, relaying reports of the disaster to the USS *Chicago* in the Pacific, which steamed at full speed to the aid of the stricken city.[12]

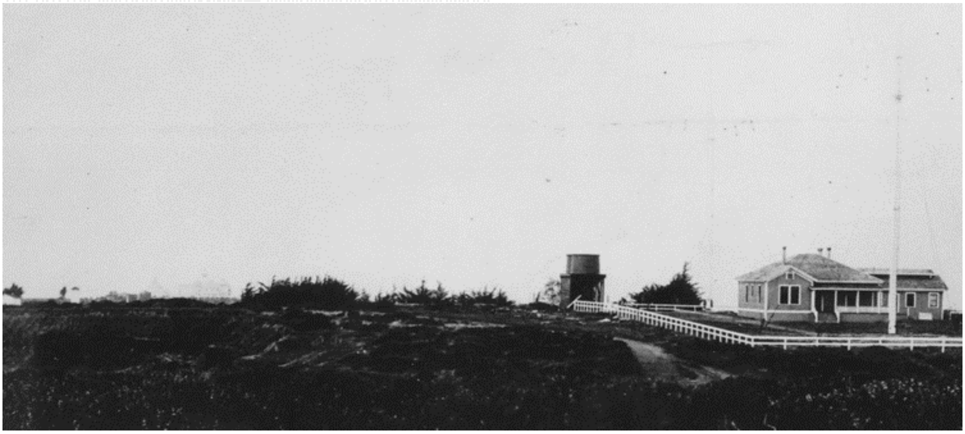
Point Loma's station had a five-kilowatt Massie Telephone and Telegraph Company transmitter, the Navy's smallest land-based standard equipment. Notwithstanding limited power, it had an impressive range of five hundred miles. The radio station established the first presence of electronic activity on the heights of Point Loma, and remained in operation until 1949, when it was moved to Chollas Heights in southeast San Diego.

Roosevelt, who had been Assistant Secretary of the Navy from 1897 to 1898, placed substantial confidence in the Navy when he assigned it major national responsibilities for radio usage and management. The service did not let him down. As entrepreneurial fervor (and financial greed) gripped the various individuals and companies vying for radio monopolies, the competition became cutthroat. Interests with significant patents refused any offers of licensing; lawsuits flourished; radio stations purposely interfered with one another's signals. The Marconi stations were particularly vilified in the latter regard, as company contracts forbade users (including entire countries such as Great Britain and Italy) from communicating with anyone operating another company's radio equipment.

to develop a memorandum, dated 1906, which states the President placed all government wireless stations on the sea coast under the control of the Navy Department by Executive Order dated July 29, 1904. That perhaps explains the date discrepancy.

[12] "Timeline of the San Francisco Earthquake," Virtual Museum of the City of San Francisco, excerpted from Gladys Hansen's *Chronology of the Great Earthquake*, and the 1906–1907 Graft Investigations.





Navy Radio Station Point Loma, commissioned in 1906, was one of the Navy's first. It was originally housed in a small frame structure, beside a dirt road that is today Cabrillo Memorial Drive. The radio station featured a Massie five-kilowatt transmitter, with an operating range of 500 miles.

The situation advanced beyond absurd when there was significant debate at the Second International Radio Telegraphic Conference in Berlin in 1906 about refusing transmission of communications from ships at sea, including during emergencies. The U.S. delegation, headed by naval officers, forced passage of the appropriate agreement to ensure cooperation, although it would take continued pressure to force reluctant radio companies to comply fully.[13]

Embracing the new technology and building additional coastal stations, the Navy installed the first radio set in the White House in 1921 so President Warren G. Harding could listen to broadcasts.

Given the broad and increasing responsibilities assigned it by the administration, the Navy required an organization to build on both commercial and military advances in the technology of radio. It fashioned one in 1923, establishing the Naval Research Laboratory in the Anacostia section of the District of Columbia and assigning it primary responsibilities for radio development.[14] The lab's pioneering role in

> development of radio equipment such as quartz crystal frequency control, high-power transmitters, and receivers led to the adoption and extensive utilization of high frequency (HF) by the Navy and had a profound effect on Naval communications for the next 50-60 years.[15]

Stanley C. Hooper

While the Washington-based Naval Research Laboratory managed major leadership responsibility for the government's use of radio, there was also an individual Navy man who contributed substantially to the service's adoption of radio communication. Past Midshipman Stanley C. Hooper, a 1905 graduate of the Naval Academy, served his first sea duty aboard the cruiser USS *Chicago*, flagship of the Pacific Squadron, which was homeported in San Diego. At the time, *Chicago* was one of the few ships boasting radio equipment. Within a few months of Hooper's arrival on board, the ship departed the port of San Francisco the evening of April 17, 1906; received news on its radio set (in a transmission from Navy Radio Station Point Loma) early the next morning of the disastrous earthquake; and steamed back at full speed, arriving just before 10:00 a.m. From

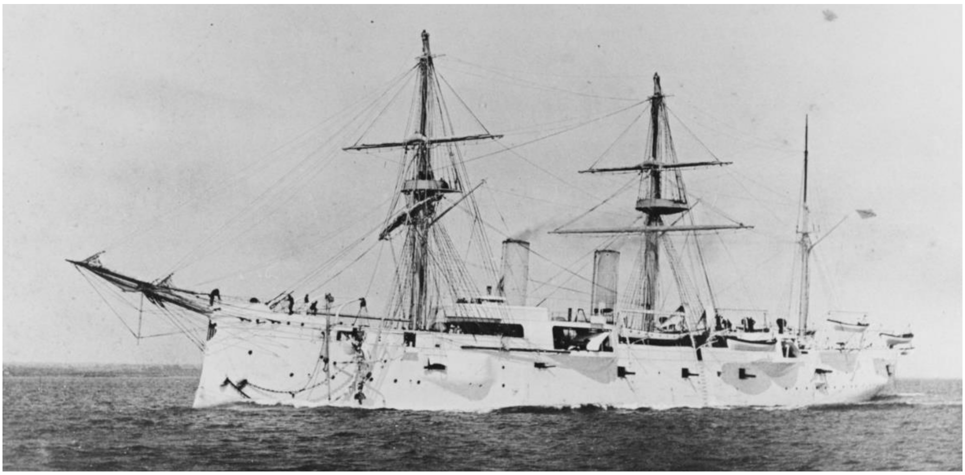
---

[13] The preceding two paragraphs summarize important points in a 17 November 1906 letter from Ambassador Charlemagne Tower to the U.S. Secretary of State, from Navy Bureau of Equipment files in the National Archives.
[14] *History of Communications-Electronics*, 535.
[15] *Highlights of NRL's First 75 Years* (Washington, D.C.: Naval Research Laboratory, 1998), 5.

the dock near the Ferry Building, crew members were sent ashore to fight fires and discourage looting. Succeeding days were spent participating in the massive ferrying of 20,000 people across the bay to Marin County and relative safety from the raging fires.

The greatest impression made on the young officer, however, was the fact the ship's radio was the city's lifeline to the outside world, and he was key to that lifeline:

> The Western Union and Postal Telegraph wires were all down and it was decided to use the *Chicago*'s radio as an outlet for all priority messages, by relaying them to the radio station at Mare Island from which place they could be telegraphed. There was no one available to take charge of this project who knew anything about the telegraph business… I stepped forward and meekly admitted my small experience as an operator at a small railroad station and two hours later found myself installed in the Wharfingage Building by the docks in charge of all outgoing messages.[16]



USS *Chicago* was one of the Navy's first ships equipped with wireless radio equipment. Alerted by Navy Radio Station Point Loma, the cruiser steamed at full speed to the aid of the stricken city of San Francisco following the April 1906 earthquake.

[16] S.C. Hooper, "Navy History—Radio, Radar, Sonar," 2R4, 10 (Washington, D.C.: Naval History Division, unpublished manuscript, undated.

Messengers ran vital communications between the young officer and his ship docked about half a block distant, and for several days until the land lines could be restored, Hooper managed all outgoing telegraph traffic.

After a subsequent assignment at the Naval Academy as the instructor in the radio course given to midshipmen, he was ordered to the Bureau of Engineering to head up its Radio Division. He repeated those fleet and bureau tours before being appointed Director of Naval Communications in 1928, an assignment that lasted six years.

According to naval historian Captain L.S. Howeth,

> During the period 1915 to 1928, Hooper was the guiding spirit in developing naval radio from little more than a toy to the essential communication medium it became. Under his direction and influence, many new features, such as the radio direction finder, appeared as standard in naval radio equipment.[17]

In the dedication of his book, Howeth singled out Hooper "for his endeavors to bring discipline out of chaos and for his efforts in making America supreme in radio communications."

The Navy laboratory on the California coast

One of those bureau reorganizations noted earlier resulted in the creation of the Bureau of Steam Engineering on July 5, 1862, four months after the Battle of Hampton Roads in which the ironclads USS *Monitor* and CSS *Virginia* initiated a new era of naval warfare. The bureau was charged with managing development of U.S. Navy ships, including the fairly recent innovation of vessels without sails. (In the Navy Appropriation Act of 4 June 1920, the word "Steam" was dropped from the title.) Its first instantiation early in the Civil War had brought some of the responsibilities of the Bureau of Construction, Equipment and Repair to the organization; in mid-1940 the current Bureau of Construction and Repair was joined to the engineering organization to form the Bureau of Ships.

While the two bureaus were negotiating the terms of the upcoming consolidation, the Bureau of Engineering chief sent a formal memorandum to the

---

[17] *History of Communications-Electronics*, 114.

Chief of Naval Operations, referencing a previous communication dated 19 May 1939 in which he'd advocated establishment of a radio and sound laboratory. His recommendation was aimed at developing some in-house capability for the Navy in an important technology area in which it was lacking. The earlier memorandum had suggested such a laboratory in a location convenient to West Coast fleet concentrations, specifically in the San Pedro-San Diego area. He reiterated his objectives from the previous letter:

> (a) To provide expert assistance convenient to the Fleet; (b) To provide qualified personnel for conducting tests of new equipment aboard ship in such a manner as to relieve operating personnel of this work which, in the past, has been reported as interfering with scheduled fleet operations; (c) To make tests involving the collection of technical data which is required in connection with design and development problems; (d) To provide the means for rotating civilian engineering personnel between the Naval Research Laboratory and the fleet in order to better familiarize such personnel with fleet problems.[18]

Secretary of the Navy Frank Knox

His follow-up letter provided new information, that coincident with the new lab proposal his bureau had been "investigating sites for a radio echo ranging field laboratory with a clear view to seaward and in an area where aircraft and surface vessels would be available as targets." He was speaking, of course, about the emerging technology that would be given the name "radar" in a year or so. (See Chapter 3.) After surveying possible locations for this second lab along the

[18] Bureau of Engineering memo to Chief of Naval Operations, 2 Feb 1940, Subject: Establishment of Radio Laboratory in San Diego Area.

Atlantic Coast and performing a cost analysis, he advised the CNO that interests of his bureau would be better served by establishing a combined laboratory in southern California:

> Such a laboratory close to the fleet and having technical personnel and facilities for engineering development work relating to installation and operating problems connected with the anticipated wide future use of radio echo ranging equipment aboard ships, should also be able to assist materially in expediting the final design and practical use of such equipment.

He also advised a suitable location had been found: a corner of the property of the naval radio station on Point Loma in San Diego, which provided the physical requirements for the desired laboratory and would not interfere with operation of the radio station. Additionally, the Army reservation to the immediate south and west had substantial undeveloped land for potential expansion. The CNO, after coordination with appropriate officials such as the Commander-in-Chief, U.S. Fleet, responded via the Secretary of the Navy that he recommended approval.[19]

Based on that interchange and subsequent actions by the Bureau of Ships, Secretary of the Navy Frank Knox issued an order establishing the U.S. Navy Radio and Sound Laboratory, effective June 1, 1940.[20]

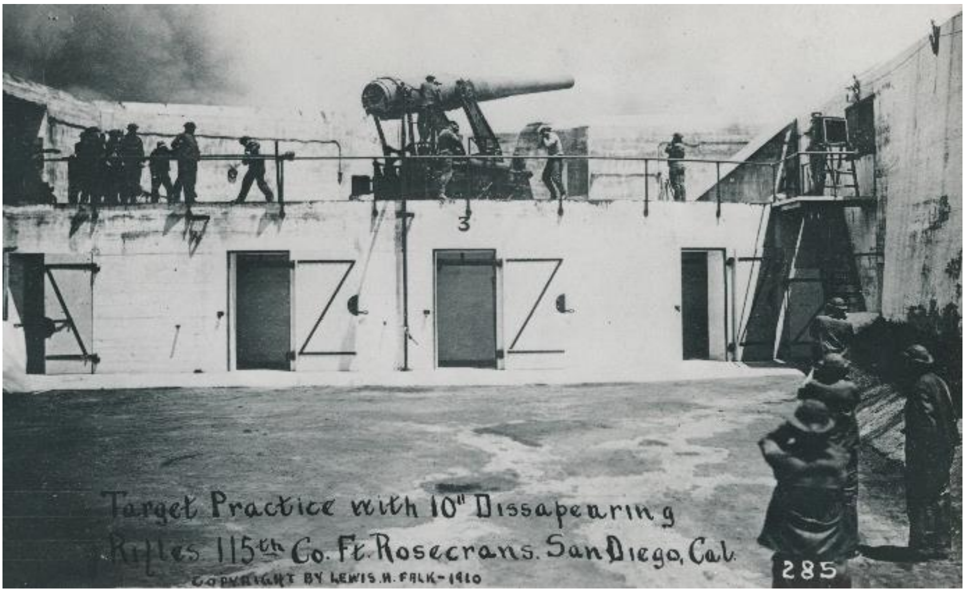
Six months before the U.S. was bombed and torpedoed into participation in the conflict already raging over vast territories in Asia and Europe, Dr. Waldo Lyon joined the small staff of that Navy laboratory, which was nearing its first anniversary at the time. His draft-deferred appointment had been orchestrated principally by his former physics instructor at UCLA, Leo Delsasso. (Delsasso, by the way, also possessed a doctorate in physics, earned at the California Institute of Technology June 13, 1941, a couple of weeks *after* Lyon received his.)[21] The lab had begun operating the previous summer on the grounds of Navy Radio Station Point Loma with a total initial staff of one Navy officer, his secretary, two civilians, and two Navy enlisted sailors.

The radio station had been communicating from Point Loma for more than three decades, and it, like the new laboratory, benefitted from the topography of the imposing land mass strategically situated at the entrance to San Diego Harbor. The peninsula of Point Loma forms the western border of the harbor, rising 422

[19] Chief of Naval Operations memorandum of March 6, 1940 to Chief of Bureau of Engineering.
[20] Secretary of the Navy letter Op-13c-je, N8-6 (390510), Serial 103113 of 27 May 1940.
[21] California Institute of Technology Commencement Program, June 13, 1941.

feet above sea level and running north to south approximately four miles from the edge of the civilian community to the tip of Cabrillo National Monument. Since 1852, much of Point Loma had been a military reserve; in 1899, the Army established Fort Rosecrans approximately in the middle of the point, building barracks and parade grounds in the area. A natural defensive formation, the commanding heights of Point Loma provide a sweeping view of the Pacific to the north, west, and south. Between the world wars, the Army constructed mortar emplacements and massive gun batteries to protect the coast and the approach to the harbor and the city of San Diego beyond. The largest of these, Battery Ashburn, boasted two 16-inch guns capable of blasting 2,300-pound shells nearly thirty miles to sea.[22]

The Point Loma location possessed four attributes of substantial significance for the scientists of the radio and sound new lab: water and direct-line-of-sight to



The U.S. Army established Fort Rosecrans on Point Loma in 1899, building coastal defense installations like Battery Wilkeson with its ten-inch "disappearing rifle," shown in 1910.

[22] National Park Service, "Cabrillo National Monument – Military History and Coastal Defense," accessed December 18, 2014, http://www.nps.gov/cabr/historyculture/military-history-and-coastal-defense.htm.

the Pacific Ocean for radio and radar research, a variety of terrain for radio experiments, the security provided by both geography and nearby naval facilities, and proximity to the Scripps Institution of Oceanography, fifteen miles to the north.

Scripps was then, as it is now, one of the premier sources of scientific knowledge about the world's oceans, and over succeeding decades there would be substantial information and personnel interchange between the Navy laboratory on Point Loma and the State of California-funded research entity in La Jolla. Perhaps most critically in those early days, Roger Revelle, a Scripps oceanographer and a naval reservist, was called up to active duty and spent some months assigned to the lab before moving on to the Navy's Bureau of Ships.

After the war, Revelle continued on a remarkable career—director of Scripps, co-founder of the University of California at San Diego, co-organizer of the seminal scientific movement the International Geophysical Year, and early theorist of both plate tectonics and global climate change.[23]

First officer-in-charge

Navy Commander Jennings B. Dow reported to San Diego for duty as the commissioning officer-in-charge of the Navy Radio and Sound Laboratory (NRSL) on June 7, 1940.[24] He was provided a temporary office at Eleventh Naval District headquarters, for what would be a relatively short assignment.

On August 21, Commander Dow initiated regular laboratory business, with support from his secretary, Mrs. Emily P. Rodd; civilian radio engineers Hugh E. Reppert and Raymond B. Owens; and Navy Chief Radiomen W.R. Fickus and D. D. Parkhurst. In less than two months, cabinet maker Henry Dykstra and machinist Willard E. Benton would join the staff of the laboratory, establishing

[23] Walter Sullivan, "Roger Revelle, 82, Early Theorist In Global Warming and Geology," (obituary) The New York *Times*, July 17, 1991.

[24] Eleventh Naval District Circular No. 29-40, dated June 7, 1940. Official correspondence, especially that between the laboratory and the Eleventh Naval District, often uses "Naval Radio and Sound Laboratory." The command's official letterhead as early as 1942 specifies "U.S. Navy Radio and Sound Laboratory."

technical services.[25] A week after the latter two arrived, on October 22, Captain W.J. Ruble reported for duty and relieved Commander Dow. It was their second mutual change-of-command.[26]

It is interesting to note the naval district circular announcing Commander Dow's arrival gave his title as "Officer in Charge." Most of the official correspondence initiated or received by his successors Captain Ruble and Captain Paul Hord used the title "Director." The NEL *Station Journal*, a monthly listing of important events initiated by Captain Rawson Bennett on June 30, 1950, begins with a "Summary 1940-1950" (obviously compiled substantially after the fact), which lists the principals at changes of command as "Commanding Officer," although almost all their correspondence for the World War II period said "Director." In his first monthly report, Captain Bennett signed approval of the document as "Commanding Officer and Director."

Given the large amount of formal correspondence signed by the "Director," we will use that title for the period of the war. When Commander J.B. Dow was relieved as director of NRSL, he traveled initially to England as an observer of radio and radar advances. He then reported to Washington, D.C., where he would serve almost the entirety of the war in the Bureau of Ships, the principal sponsor of the technical work at the Radio and Sound Lab and its immediate successors.[27] Captain Ruble, as the new director of NRSL, moved the laboratory forward in its primary function of studying and improving communications technology for Navy ships at sea.

NRSL assigned antenna evaluation

In its first decade and a half of operation, the Naval Research Laboratory substantially widened its areas of interest and study to a variety of technologies

---

[25] Navy Electronics Laboratory *Station Journal*, "Summary 1940-1950".
[26] *History of Communications-Electronics*, 420. From October 1933 until June 1938, as a Navy commander, Ruble had headed the Radio Division of the Bureau of Engineering, one of the two bureaus consolidated to form the Bureau of Ships in June 1940. He was relieved in that position by none other than Lieutenant Commander J.B. Dow, who held it from June 1938 until January 1940, shortly after which he reported to lead NRSL as the first commanding officer and director.]
[27] *Proceedings of the I.R.E. and Waves and Electrons*, May 1946, 323.

important to the Navy. While this was an appropriate expansion, it also reduced the necessary concentration on the essential technology of communication.

Retired naval officer David Boslaugh, commenting on the criticality of electronics research in prosecuting modern warfare, wrote,

> It had become clear in the opening months of World War II that the Navy was going to develop and use new electronic devices on an unprecedented scale, particularly in communications, radar, and underwater sound. But electronics research was just one small facet of the workload at the Naval Research Laboratory which had responsibility to work in all areas of science and technology. The need for a separate laboratory dedicated to research, development, and engineering of electronics equipment for Navy applications became acutely apparent, and in 1942 [sic] the U.S. Navy Radio and Sound Laboratory was established at San Diego, California.[28]

(The actual establishment of NRSL was in 1940.)

By the early days of World War II, the Naval Research Lab had its hands full with a wide array of research efforts for the Navy. The newly established Navy Radio and Sound Laboratory began in its first months of operation to evaluate the NRL-developed technology for using HF radio waves for communication with Navy ships at sea. Although NRSL was situated on the heights of Point Loma, its personnel spent a good deal of time on the water in San Diego Harbor, circling ships anchored in somewhat open spaces and performing a variety of measurement and evaluation studies to determine their communications equipment efficacy.

The two civilian radio engineers (with others who joined them over succeeding months) and their Navy enlisted counterparts conducted signal strength measurements of those ships, issuing formal numbered reports every three to six months on their findings, which were forwarded to the Bureau of Ships.

While shipboard antenna measurements were underway in San Diego Harbor and some miles to sea west of Point Loma, newly hired NRSL technical personnel were working on several other areas of interest. Based on the laboratory's formal reports issued during the Second World War, those personnel were conducting studies in the operational capabilities of radar, in the physics of the atmosphere, and in the science of underwater acoustics. (As will be discussed shortly, the latter efforts would occupy lab personnel for decades, and a number of early ones would

[28] David S. Boslaugh, *When Computers Went to Sea: The Digitization of the U.S. Navy* (Los Alamitos, California: IEEE Computer Society, 1999), 63.

be pursued jointly with personnel of the University of California Division of War Research after it was established in mid-1941.)

One of those closely involved was Waldo Lyon, who, as he said, was

> really learning acoustics in submarines and working on problems of sonar and submarine detection. But from the submarine's point of view, right from the start, I was not really antisubmarine warfare. I was pro-submarine warfare to begin with… naturally, we learned about harbor-defense systems of all types and then what submarines could do using the currents, temperature profiles, and what not, of a particular place to avoid being detected getting into harbors.[29]

As an obvious corollary to that, his group was able to improve harbor defense systems, such as the one established at the entrance to San Diego Harbor a mile south of the NRSL waterfront area.

The communicator

The flagship of the Battle Fleet, USS *California* (BB-44), was the last American battleship built on the West Coast, and the first duty assignment of Ensign Rawson Bennett, a native of that state. He was next assigned communication duty on the staff of the Battle Fleet commander.

After several subsequent ship assignments, he returned to the Naval Academy, at which he had been commissioned in 1927, for postgraduate training in radio (electronic) engineering. Additional studies resulted in a master of science degree in electrical engineering from the University of California.

Resuming his duties at sea after several years in the classroom, he served as radio and sound officer on a destroyer division staff. As additional duty, he established and managed the technical program of the first Fleet Sound School in San Diego. In that role, he had occasion to work closely with personnel of the newly established U.S. Navy Radio and Sound Laboratory located nearby.

Bennett spent the World War II years in the Navy's Bureau of Ships, working on underwater sound technologies and electronic design. His Legion of

---

[29] *The Reminiscences of Dr. Waldo K. Lyon* (Annapolis, Maryland: U.S. Naval Institute, 1972), 3-4.

Merit for that tour included a specific citation for his design of "sonic and supersonic underwater sound apparatus so urgently required by the Fleet for the destruction of Axis submarines and Japanese shipping."

Shortly after the end of the war, he returned to the Radio and Sound Lab, now the U.S. Navy Electronics Laboratory, as its commanding officer and director.[30]

Rawson Bennett photo from the Naval Academy yearbook of 1927

The Navy laboratory in the California desert

The Navy's second laboratory on the West Coast originated with a university's pioneering technology development effort and a naval aviator's first-hand disappointment with the weapons he was given to defeat the enemy. California Institute of Technology, like the University of California, was one of hundreds of U.S. universities volunteering for and participating in the nation's

[30] Rear Admiral Rawson Bennett II biography, Naval Research Laboratory.

defense of its safety and sovereignty. Finding its niche in the development of weapons, and particularly rockets, Caltech performed the vast majority of its research in this field in laboratories on its own campus in Pasadena or in hardware development and manufacturing facilities scattered around the area. Essential testing of its products was done initially in a somewhat remote canyon area northeast of the city.

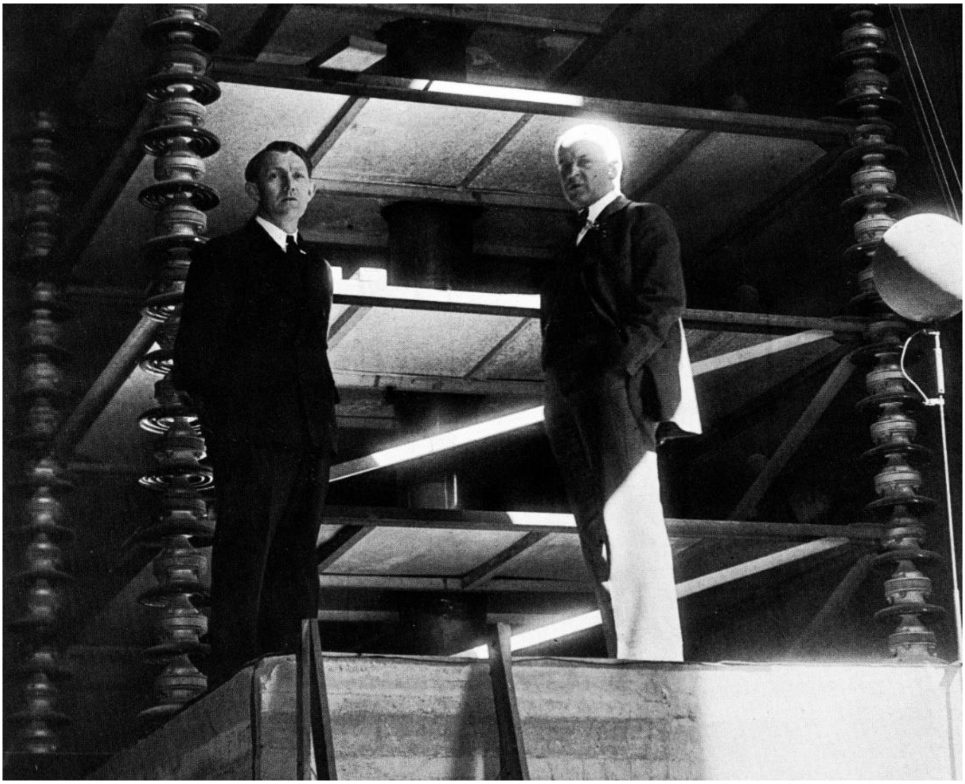
When several university weapons workers died in explosions and resulting fires, and when rocket development work advanced to the stage that it required fairly long-distance firings, it was clear the heavily populated metropolitan area around Pasadena was no longer workable. Alternate sites were researched and arrangements were made for Caltech to use them for testing: Goldstone Lake, site of the Army's new Mojave Anti-aircraft Artillery Range facility near Barstow, several hours' drive northeast of Pasadena, and the Marine Corps' Camp Pendleton, about an hour's drive to the southwest along the California coast. Although both were improvements, neither was very suitable for the testing requirements. Through the mutual efforts of two fairly different individuals who happened to think along fairly similar lines, those requirements would be met with extraordinary success.

The rocket scientist

Danish-born Dr. Charles Christian Lauritsen emigrated to the United States in 1916 with a degree in architecture. Designing buildings soon gave way to a fascination with the nascent technology of radio, and by the early 1920s he was in Palo Alto, California, tinkering with new designs for radio receivers and working on ship-to-shore communications. An engineering job at the Kennedy Corporation (a producer of radio receivers) in St. Louis, Missouri, led to the meeting that would change the course of his career and give Caltech its most brilliant inventor of the Second World War.

Lauritsen attended a lecture by Caltech's Nobel Laureate, physicist Robert Millikan, who was sufficiently impressed in conversation after the lecture to invite Lauritsen to Pasadena. The Dane would earn his Ph.D. and become a member of the physics department faculty in 1930. His wife Sigrid, one of the first women to graduate from the medical school at the University of Southern California, worked as a radiologist, and here their talents converged. Throughout the 1930s, Lauritsen perfected high-voltage X-ray tubes, useful in physics research as well as in medical therapy.

In 1940, the year his native Denmark was overrun by Hitler's army in six hours, Lauritsen turned his impatient mind to weapons design. He had served as an advisor to the National Defense Research Committee (NDRC) and its successor Office of Scientific Research and Development (OSRD) in Washington, but quickly came to resist the military's attempt to centralize the design and testing of advanced weapons. Lauritsen returned to Caltech in the fall of 1941 at the urging



Charles Lauritsen (left) and Dr. Robert Millikan stand atop the million-volt x-ray tube developed and built by Lauritsen and associates at Caltech in 1928.

of Millikan, who wrote, "I feel pretty sure that you can make a bigger contribution here than you can in Washington…. it is our job to concentrate every available effort on the things that have some promise of helping within [a year's] time."

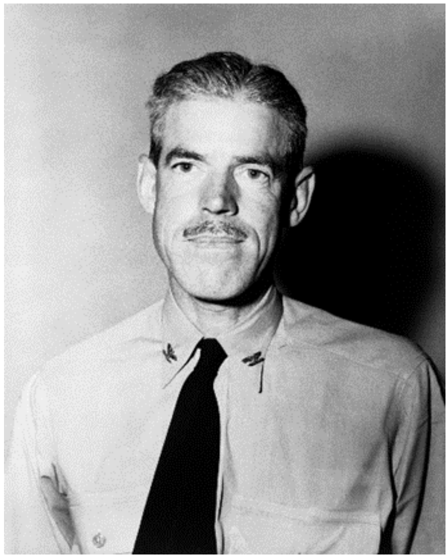
During his final months at NDRC/OSRD in Washington, Lauritsen traveled to London to examine the Brits' program for developing rockets, an area of increasing interest to the Caltech professor. He returned with his mind set on rocket development. Like the man who would very soon become his close associate, Captain Sherman Burroughs, his path would lead him to the desert.[31]

The carrier pilot

Sherman E. Burroughs was among the pioneers of naval aviation. The 1924 Annapolis graduate earned his wings in 1926 and served on USS *Langley*, America's first aircraft carrier, the following year. By 1938, he was senior aviator on the battleship USS *Arizona*. On December 7, 1941, as the Arizona settled into the mud on the bottom of Pearl Harbor, Burroughs was serving on the staff of Vice Admiral William F. "Bull" Halsey, Jr. Almost immediately reassigned to where the real action was, the aviator quickly distinguished himself in combat, earning two Silver Stars and a Distinguished Flying Cross for heroic actions in battles at Midway, Wake, and the Solomon Islands. He knew what naval aviation weapons could—and could not—achieve. Concerned that Navy pilots needed a better arsenal in the air, particularly and personally after the loss of many of them in his squadron at Midway, Burroughs advocated the creation of a dedicated aircraft weapons development center. In March 1943, Halsey supported the reassignment of Burroughs to the Bureau of Ordnance in Washington, D.C., saying, "Go back and get things straightened out back there! Try to get those guys off the dime!" Although he would spend the spring of 1943 in the recently dedicated Pentagon, the carrier pilot from Manchester, New Hampshire, would move shortly to a different environment altogether, as the first commanding officer of the Navy's second laboratory in California. He would play a critical role in its establishment and first years of producing better aircraft weapons for the Navy, not onboard ship or even near the water, but on a flat, scorching plain in the Mojave Desert.[32]

[31] Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 1: Sailors, Scientists, and Rockets* (Washington, D.C. Naval History Division, 1971), 168.

[32] J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 2: The Grand Experiment at Inyokern* (Washington, D.C. Naval History Division, 1978).



Captain Sherman E. Burroughs

Mutual desire for test range

In about July of 1943, shortly after the newly promoted Captain Sherman Burroughs had reported to the Bureau of Ordnance as its assistant director of research and development, he traveled west to visit Dr. Charles Christian Lauritsen of the California Institute of Technology and hear about his rocket development program. Lauritsen took him out to the Goldstone Lake range to witness some tests, and, with a keen sense of what might be impressive to the captain, sent him up in one of the test planes to fire some rockets. Understandably, Burroughs *was* impressed.

Chatting afterward about their mutual interests and concerns, the two men were pleased to discover a mutual desire for a suitable range for testing rockets and other Navy developmental ordnance. Stimulated by that conversation and the statement of support from a senior officer in the Bureau of Ordnance, Dr. Lauritsen immediately began a personal search for a location to establish such a range.

As will be related in appropriate detail in Chapter 4, the next time he saw Captain Burroughs, he took him to view his discovery in a remote and generally uninhabited section of the Mojave Desert.

While the university professor went back to his research lab in Pasadena to continue development of new weapons, the naval officer went back to his bureau in Washington and began enlisting support for a test range sited specifically in the locale he'd been shown. Although the civilian researcher and the career military man had different points of view on the test range (a physical area for design and evaluation of weapons needed immediately for the war, versus one to ensure the Navy had a weapons development area for decades to come), the desert location discovered by Lauritsen and championed by Burroughs answered both men's interests and requirements.

Acknowledging the gears of government bureaucracy often move slowly and sometimes grind to a noisy halt, the military officer pursued the test range plan with enthusiasm and perseverance. His pursuit was successful. On November 8, 1943, the same Secretary of the Navy who had established the U.S. Navy Radio and Sound Laboratory on the Pacific in San Diego established a new weapons laboratory, the U.S. Naval Ordnance Test Station (NOTS), several hundred miles to the northeast in the Mojave Desert, at a small town called Inyokern.

Test station established

The establishing order was short and to the point: "A station, having for its primary function the research, development, and testing of weapons, and having additional function of furnishing primary training in the use of such weapons, is hereby established and designated. U.S. Naval Ordnance Test Station, Inyokern, California."

In addition to championing the establishment of the station, Captain Burroughs had developed a detailed plan listing significant advantages of such a station and primary facilities required for what he envisioned as its mission.[33] He also proposed a suitable commanding officer—himself, and suggested he and a

[33] *Sailors, Scientists and Rockets*, 190.

small group of officers he named be sent immediately to California to begin preparation for setting up the station.

He was substantially disappointed when his superiors turned down both the proposal and the suggestion. The various negatives notwithstanding, however, Captain Sherman Burroughs arrived at the landing field adjoining the new naval station's property as its first commanding officer on or about December 21, 1943. On that date, there was little to command.

While the NRSL commanding officer in San Diego had some facilities to work with from the outset—barracks built for Army coastal defense battery gun crews and an office/laboratory building borrowed from the co-located Navy radio station, plus a fair-sized city right outside his main gate—the NOTS commanding officer had nothing but alkali flats, creosote bushes, and a "town" of about twenty-five people nearby. And unlike his counterpart at NRSL, who started with a handful each of civilian and military personnel and saw reasonable if slow growth in those numbers, the NOTS CO had only military personnel—four officers and not even a handful of enlisted. (Two months after the station was officially established, he reported to a superior officer with some unhappiness that his entire "staff" consisted of one yeoman.[34]) It would be months before the Navy laboratory had any civilian employees.

In the meantime, with his slowly increasing complement of military personnel, he had to provide range support and other services to those California Institute of Technology professors and staff members who would appear somewhat randomly, conduct a few test firings, and then head back to the real world in Pasadena.

Fortunately, he had the substantial support of the Bureau of Ordnance and, more to the point at the time, of the Bureau of Yards and Docks. The latter sent him officers to supervise construction of essential facilities in the middle of nowhere.

Most importantly at the outset, Captain A.K. Fogg, the public works officer for the Eleventh Naval District, headquartered in San Diego, was appointed acting in that role at NOTS for several months when the only "improvement" on the desert landscape was the landing field. By the time Captain Burroughs landed at that field to take charge, Fogg already had unassembled Quonset huts on the

[34] *Sailors, Scientists, and Rockets*, 199.

railway siding at Inyokern. (Fogg was so efficient that the huts were actually on rail cars rolling toward the desert the day Secretary Knox signed the establishment order).[35] The public works officer also had a contract in place with a construction company to build those huts into temporary quarters and offices.

Fogg not only got the temporary facilities well underway, but also, with substantial assistance from two Bureau of Ordnance officers sent to Pasadena to assist in the planning, managed to create the first set of plans and drawings for the permanent facilities as well. With that fairly remarkable feat of achievement in a very short time, he turned the assignment over to his relief, who explained the marching orders.

Newly promoted Captain Oscar A. Sandquist, the first permanent Officer-in-Charge-of-Construction of the new test station, put it succinctly: "BuOrd wanted this Station to be the best of its kind and ultimately to be a permanent one—to keep up with developments and thus be an insurance to scare off future aggression and wars. The groundwork and progressive planning were based on this principle."[36]

Permanent facilities

Sandquist arrived at his new assignment on January 15, 1944. Over the next ten or so months, he would oversee the construction of hundreds of buildings, from military housing to laboratories to machine shops to recreational facilities for both military and civilians. Many were temporary structures like those Quonset huts, but given the marching orders that the end of the war would not signal the end of the test station, concrete footings were poured in numerous locations and permanent buildings placed on them. Perhaps the most noteworthy thing Sandquist did on behalf of the Navy establishment for which he was constructing those buildings, however, was to point out the station headquarters had been sited at the air field, whereas the main construction for administrative and weapons development facilities was taking place ten miles east, at China Lake. Moving those unassembled Quonset huts that ten miles would allow the commanding officer to

[35] *The Grand Experiment at Inyokern*, 28.
[36] Oscar A. Sandquist China Lake interview, July 6, 1966, 11 and 18.

set up shop immediately at what would become his focal point of permanent operations. With a quick phone call to the Bureau of Ordnance for approval, headquarters of NOTS was moved from Inyokern to China Lake.[37]

In the last few weeks of 1943, before Captain Burroughs had arrived as CO and a month more before Captain Sandquist had appeared as his facilities coordinator, the U.S. Congress had passed the Public Works Appropriation Bill. It allocated $9.5 million for the Naval Ordnance Test Station. The Navy released the funding February 15, 1944, but by then it had become obvious construction of the numerous and varied facilities planned for the desert site would cost nearly $24 million. Once again, however, the NOTS commanding officer had a friend at the Bureau of Ordnance.

The new BuOrd chief, Rear Admiral George F. Hussey, made a whirlwind trip to California during a major thunderstorm in the Pasadena area that turned into an even more violent sandstorm in the desert, where bulldozers had broken up the compacted earth into innumerable fine grains of sand. Despite the gritty taste of the lunch he was served in the temporary mess hall, and the fact the rocket test he attended was virtually invisible in the moving wall of sand, Hussey liked what he saw and heard about progress at China Lake. He authorized Captain Burroughs to forge ahead with the aggressive building program for the Navy's weapons development facility of the future, promising he would get the additional funds. True to that promise, upon his return to Washington he wrote to the Chief of Naval Operations, seeking half of the $14 million shortfall to be added to the 1945 Public Works Appropriation Bill. He supplied the other half from his own bureau's funds in the 1944 Supplemental Bill.[38] Although it would take several years and substantially more dollars to achieve the Navy testing station envisioned by those with a concept of what might be, the permanent Naval Ordnance Test Station, headquartered at China Lake (physically now and eventually officially), was on its way to that promising future.

---

[37] *Sailors, Scientists, and Rockets*, 228 and also *The Grand Experiment*, 33. Despite the "assurance" voiced in the latter citation, it would be more than a decade before the Secretary of the Navy officially changed the headquarters location to China Lake.
[38] *The Grand Experiment*, 124-5.

THE UNIVERSITIES

America's universities represented an unparalleled, and mostly untapped, resource at the start of World War II. The First World War had shown some promise in this regard, as a small number of institutions of higher learning, most notably the California Institute of Technology, had sent delegations to Washington, D.C., offering use of their research laboratories and their professors to assist the country in developing needed technologies to support the war effort. Politics and perhaps timing prevented the realization of any of the well-intended offers of scientific support for that effort.

The Treaty of Versailles, ending hostilities between Germany and the Allied Powers and marking the conclusion of the First World War, was signed June 28, 1919. It included numerous terms to prevent a resumption of hostile action. Those included Article 181, which ordered that "no submarines are to be included" in naval vessels Germany could maintain for national defense. While paying lip service to that article, the Third Reich secretly constructed a fairly robust submarine force in the 1920s and 1930s. As years passed and memories faded, Nazi Germany augmented its military might and increased its incursions into and invasions of its European neighbors, and those submarines initiated numerous attacks on warships, military supply ships, and even unarmed passenger liners.

On September 3, 1939, hours after the new European conflict officially commenced with declarations of war by Britain and France, a German U-boat (from the German *unterseeboot*) torpedoed a British passenger ship carrying a large number of Americans. Subsequent attacks in the Atlantic forced the United States to realize that continued neutrality was improbable.

Recognizing the most pressing requirement if the U.S. entered the conflict would be to counter the U-boat threat, the Navy's concern about its ability to fight underwater prompted it to seek independent review of its capabilities in that arena. In response, the Naval Advisory Committee of the National Academy of Sciences formed the Subcommittee on Submarine Detection in late 1940.

The group was tasked "to analyze America's ability to fight a submarine war, and in particular, to review the state of submarine detection…" initially "concerned only with the detection and location of submarines from Navy surface craft," which it concluded to be substantially inadequate.[39] The subcommittee's final report in January 1941 recommended "a broad research program in underwater acoustics and oceanography" to correct that deficiency. With the report in hand, the chief of the Navy's Bureau of Ships requested assistance from the National Defense Research Committee (NDRC) in developing a program to improve the service's warfighting capability, specifically focused on subcommittee recommendations. The national committee responded with a proposal for a joint NDRC-Navy program to conduct research and development in technology areas critical to undersea warfare. The proposal, in addition to recommending the Navy seek technical support from private industry, universities, and existing government research institutions, called for establishment of two laboratories, one on each coast, to support improvement of Navy anti-submarine warfare (ASW) capabilities.

The report also provided some specificity to the proposal:

> It was further recommended that the Atlantic Coast laboratory, because of its proximity to Washington and large manufacturing centers, be concerned with the development of equipment and the final design of prototype gear, while the Pacific Coast laboratory would concern itself primarily with fundamental investigations which, it was hoped, would suggest promising techniques or procedures for detecting and successfully combatting [sic] submarines.[40]

After appropriate discussion, the Navy adopted the proposal. Taking advantage of numerous pre-war offers of assistance from the nation's universities, Columbia University in New York City and the University of California were asked to set up, staff, and operate the labs under contracts to be issued by NDRC.

University of California

The College of California was chartered in 1855, acquiring a building site in Berkeley five years later. Following President Abraham Lincoln's signing of what

[39] Robert Gannon, *Hellions of the Deep* (University Park, Pennsylvania: The Penn State University Press, 1996), 55.
[40] *Completion Report*, University of California Division of War Research, 30 June 1946, 14.

was popularly known as the Morrill Act, the California state legislature established the Agricultural, Mining and Mechanical Arts College in 1866.[41]

In 1867, the College of California offered its buildings and land to the state on the condition it establish a "complete university," teaching humanities as well as mining and agriculture. The resulting University of California (UC) was not a merger of the two, but rather a new institution receiving value (land, buildings, and money) from its two predecessors.

The university's first classes were held in Berkeley in 1873. Over the next decade, additional university facilities were established in several cities that would eventually evolve into major UC campuses. Of significant importance shortly to this history, the university accepted as one of its remote "departments" the San Diego Marine Biological Association in La Jolla in 1912. It subsequently became the Scripps Institution of Oceanography and eventually an important part of the university's San Diego campus.

In 1919, the Los Angeles Normal School became the Southern Branch of the university, renamed eight years later University of California at Los Angeles. Growth spurted: "By 1923, the University of California led the universities of the United States and the world in enrollment, with 14,061 full-time students—surpassing that of Columbia University."[42] At that time, more than a third of those students attended classes at the Los Angeles campus.

Dr. Knudsen selected to lead division

With the NDRC decision to contract operation of the research-focused submarine warfare lab to the University of California, Dr. Vern O. Knudsen, dean

---

[41] Edmund J. James, Ph.D., LL.D., *The Origin of the Land Grant Act of 1862, and Some Account of its Author*. (University of Illinois, The University Studies, Vol. IV, No. 1, November 1910), 32. Actually titled "An Act Donating Public Lands to the Several States and Territories which may provide Colleges for the Benefit of Agriculture and the Mechanic Arts" and sponsored by Vermont Congressman Justin Smith Morrill, it granted states 30,000 acres in public land for each of its U.S. senators and congressmen, the land to be sold and proceeds used to fund public colleges focused on agriculture and mechanical arts.

[42]http://www.lib.berkeley.edu/historygeneral_history/overview/tour1.html,visited December 24, 2016.

of the graduate school at UCLA, was appointed special investigator on May 13, 1941.[43] His task was to supervise the establishment and operation of the new organization, which the Navy had determined would be located at its Radio and Sound Laboratory in San Diego. This would be the first collaborative effort between the Navy and the University of California on wartime research. The name initially provided the organization was the University of California Division of National Defense Research.[44]

More than any other person, Knudsen had been responsible for UCLA's reputation as a leader in acoustical research. (His university staff assistant, incidentally, was Leo P. Delsas/so, who had left UCLA already and was serving in uniform as the assistant director of the Navy lab in San Diego that Dr. Knudsen was selected to support.) Over the next several months, Knudsen recruited university professors and other scientists who could contribute to the execution of the NDRC tasking and set them to work on specific projects. With his extensive contacts, he even brought the director of Scripps, Dr. Harald U. Sverdrup, to Point Loma to work on pressing scientific issues, until overzealous agents of the Federal Bureau of Investigation stripped him of his security clearance.[45] While Knudsen recruited and matched scientist with research task, the NDRC itself worked administrative details, including developing necessary contracting documents. Given the urgency and importance of their tasking, the lab initiated projects before those documents were drawn up, with the university providing interim funding.

The acoustician

Acoustics would be the single most important subject of interest on Point Loma as war germinated and then bloomed in awful profusion. It was believed the enemy knew a lot more about it than the U.S., and it was one of the key responsibilities of the Navy laboratory and the NDRC's university contractor to

[43] Knudsen, a 1915 graduate of Brigham Young University, received his doctorate in physics from the University of Chicago in 1922. Co-founder of the Acoustical Society of America, he served as its president 1933-35. In the middle of that (1934), he was selected dean of the UCLA graduate school, a post he held for twenty-four years, including the World War II era. He served as chancellor of UCLA 1959-60.

[44] *Completion Report*, 15.

[45] Walter Munk and Deborah Day, "Harald U. Sverdrup and the War Years," *Oceanography*, Vol. 15, No. 4, 2002, 1 and 12. Also see Chapter 3 below.

change that. On July 1, 1941, Dr. Ralph Christensen and two others joined the staff of the nascent University of California Division of National Defense Research (effectively doubling it) to initiate that process. Shortly thereafter, Christensen's undergraduate mentor at Brigham Young University (BYU), Dr. Carl Eyring, would add his name and credentials to the burgeoning University of California division's personnel list. Together the two scientists would author half a dozen reports on behalf of the organization, the most significant of which announced their discovery with Russell Raitt of the Deep Scattering Layer.

Christensen was a 1928 graduate of BYU, at the time the leader among western universities in audio acoustics, and his degree in that field enabled a teaching fellowship at the University of California in Berkeley. His simultaneous laboratory work earned him a master's degree in 1930 and a Ph.D. two years later. He then traveled across the bay and a short distance south on U.S. 101 to settle into a teaching career at San Mateo Junior College. When UCLA's (and fellow BYU graduate) Dr. Vern Knudsen was asked to establish the university's organization to support Navy ASW efforts, one of his early recruits was Christensen, whose graduate work at Berkeley was known to him.

Like many of his UC associates, Christensen would stay after the war, joining the staff of what shortly became the Navy Electronics Laboratory (NEL), and advancing from Sonar Branch head to manage the Signal Propagation Division. He became acting technical director in 1960, and in 1961, after a nationwide search, was selected as technical director.

During the late 1940s and 1950s, he administered major studies of reverberation effects, long-range sound propagation, and deep-water echo-ranging. These studies generated a tremendous amount of data requiring analysis. Christensen saw the potential of computers, and under his direction, NEL embarked on a major expansion of its computing facilities and personnel.

The principal focus of NEL in those years was not systems development, but pursuit of fundamental research that laid the foundations for later systems, a philosophy Christensen specifically endorsed. He encouraged NEL researchers to publish papers in scientific journals to maintain intellectual standards on par with those of leading universities and private research institutes and likewise encouraged pursuit of patents.

Military experience lacking

With contracts and funding processes in place, the two challenges facing the UC division were the lack of experience of academic scientists and engineers with military problems they were expected to solve, and the fact the memorandum under which the UC personnel were to be assigned work tasks "had not outlined the division of responsibility between the Directors of the Navy Laboratory [NRSL] and UCDWR with sufficient clarity."[46] The appropriate solution to both challenges resided in frequent interaction with uniformed personnel assigned to the Point Loma Navy laboratory (whose civilian personnel suffered some of the same problems) and the fleet sonar school, the nearby submarine squadron, and other Navy commands in the San Diego area.

The NDRC principals with whom the UC contractors were to work operated from offices in New York. Less than a year after his selection as special investigator for the University of California ASW lab, "Dr. Knudsen's services for work with the central directing organization of NDRC were urgently requested," and he moved to New York for the duration of the war. His deputy, Dr. Gaylord P. Harnwell, succeeded him as director of the lab on April 1, 1942.[47]

Some months before the leadership change, in the fall of 1941, the organization's name had been changed officially to University of California Division of War Research (UCDWR).[48] The division was also referred to simply as the San Diego Laboratory. Previous histories inaccurately ascribed this title to the "combined establishment of NRSL/UCDWR."[49]

Perhaps the best description of the relationship between the co-located Navy lab and university contractor can be found on the first two pages of UC Report F100 of August 1, 1943, "General Information for Staff Members." In essence

---

[46] *Completion Report*, 16.
[47] *Completion Report*, 24.
[48] *Completion Report*, UCDWR, 15, and UCDWR Bi-Weekly Reports October 18-31 and November 1-14, 1942.
[49] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*, NOSC Technical Document 1940, 1990, 7. Careful reading of the *Completion Report* and the division's bi-weekly [sic] reports to OSRD/NDRC demonstrate clearly that UCDWR was "the San Diego Laboratory" of NRDC, as the Columbia University division was titled "the New London Laboratory." Those reports include "San Diego Laboratory" and "Navy Radio and Sound Laboratory" as separate entities on their distribution lists.

what could be termed reasonably a "new employee handbook," it states in an introductory manner:

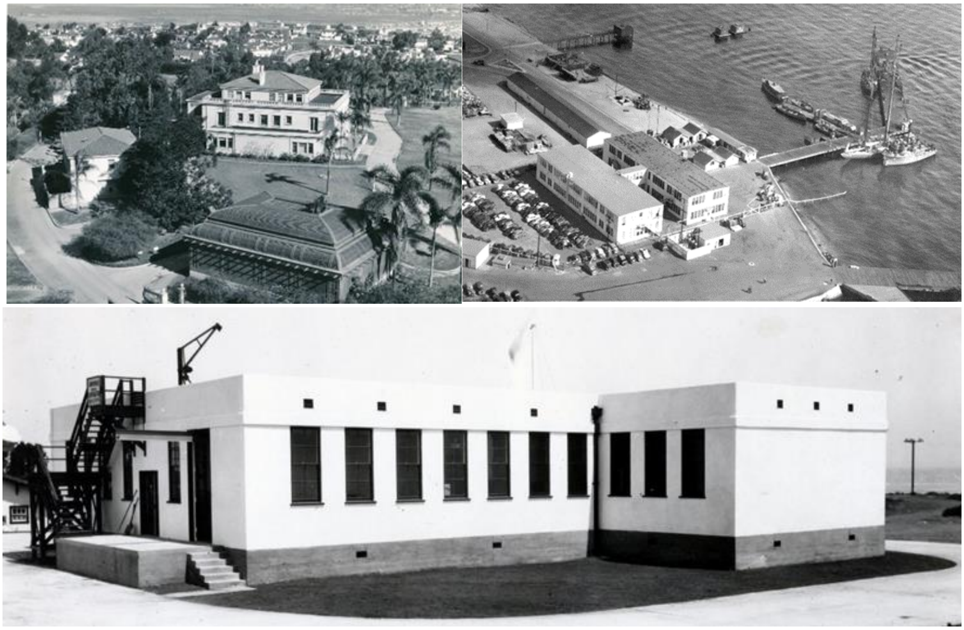
> You are a member of the staff of a special research laboratory established for the specific purpose of assisting the U.S. Navy in sub-surface warfare activities Technically, you are an employee of the University of California, working under provisions of a contract entered into between the University and the Office of Scientific Research and Development… Although the product of our work is for the Navy and we are within the boundaries of the U.S. Navy Radio and Sound Laboratory and the West Coast Sound School, we are not employed by the Navy. We should rather consider ourselves as guests of the Navy and striving toward the solution of common problems.

Although there was apparently much interactive work, each organization had its own management and staffing, rules and procedures, and set of required progress reports. UCDWR made biweekly reports to OSRD/NDRC, and NRSL submitted formal technical reports, quarterly progress reports, and Sound Division biweekly reports to the Bureau of Ships. While UCDWR was working almost exclusively on sonar and ASW efforts that included training personnel in use of appropriate equipment, NRSL was conducting antenna strength measurements of ships in the harbor, developing radar capabilities and training radar operators, and initiating the pro-submarine work discussed below, an area UCDWR joined when they had successfully supported the demise of the U-boat threat.

The university division was initially co-located with NRSL at its headquarters in Building 4 on the grounds of Navy Radio Station Point Loma, but with the growth in personnel and projects in both organizations, the Navy built two adjacent buildings, Buildings 1 and 2, for contract personnel. While the half-basement of Building 1 housed a shared cafeteria and the UC division machine shop filled the basement of Building 2, the upper floors of both structures provided laboratory and office space for UCDWR employees.[50] All three of the buildings were painted in camouflage during the war.

As the UC personnel roster grew, the Navy constructed another building at the Naval Training Station. While Building 3 (later 3E when another, semi-attached structure was added) was three miles away from the NRSL/UCDWR headquarters, it was on the waterfront, with an adjacent pier built for the many required sea tests. Additionally, it was close to the U.S. Fleet Sonar School, which the university division supported substantially. As Navy lab and university division populations increased, another building, 3W, was constructed on the site,

[50] *Completion Report*, 92-93.



Early facilities of the Navy lab and the UC contractor included the Bridges Estate (top left); UCDWR Buildings 3 E&W at the Naval Training Station, on the water and in close proximity to the Navy Sound School (top right); the lab's first headquarters, Building 4, in its initial simplicity (bottom).

with a second-story enclosed "bridge" connecting the two structures. Completed in August 1945, Building 3W allowed the move of UCDWR personnel to the waterfront, making room for NRSL personnel in Building 1.

Smaller buildings were constructed in the headquarters area for support services. UCDWR even leased a nearby private mansion, the Bridges Estate, located about a block from what is now Point Loma High School. (During the war and for several decades afterward, it was a junior-senior high school.) The Bridges Estate on Alcott Court was offered by the family to the Navy for its use at the beginning of the war. UCDWR housed supply personnel, publications people (writers, editors, and graphic designers), and some financial people in the facility, which was given the intriguing title "Building X."

In addition to the Point Loma work spaces, a large number of UCDWR personnel worked not only out of state, but on the other coast. NDRC requested UC leadership to provide a minimal staff to support selection and training work for their Division 6, established to oversee prosecution of the U-boat problem. From mid-1943 until the following spring, the UC personnel occupied a small amount of space in the Empire State Building in New York City. Follow-on tasking to revise a set of Navy sonar maintenance manuals required personnel strategically located for reasonable collaboration with the Executive Office of the Secretary of the Navy, the Bureau of Ships, and appropriate publishing firms. That effort boosted the UC staff in the famed skyscraper to the point it required 8,000 square feet of additional space.[51]

The UC division, with Dr. Knudsen and then Dr. Harnwell recruiting heavily as the NDRC task assignments increased in number and complexity, grew from "a small, loosely knit group of a score of scientists in the summer of 1941 to an integrated organization of some 600 persons comprising physicists, engineers, geologists, psychologists, writers, artists, machinists, draftsmen, and so forth by the summer of 1945."[52]

Three scientific divisions

Organizationally, in addition to the Eastern Operations group, the UC operation had an engineering services division, a business division, and three scientific divisions: Sonar Data, Sonar Devices, and Training Aids. The Sonar Data Division emphasized what NDRC had initially assigned to the West Coast organization, fundamental research, in which physicists and acousticians studied "all acoustic propagation phenomena."[53]

The Sonar Devices Division pursued "design, development, production, installation, and operational testing" of anti-submarine sonar devices. In its original statement to the Navy about establishing two ASW labs, NDRC had specifically recommended the Atlantic Coast laboratory be assigned "development of equipment and the final design of prototype gear." The Pacific lab was to concentrate on the research, which might "suggest promising techniques or procedures for detecting" submarines. Unwritten, perhaps, was the notion that if

---

[51] *Completion Report*, 198.
[52] *Completion Report*, 22.
[53] *Completion Report*, 34.

such techniques emerged, the related hardware development would be assumed by the "eastern laboratories," as the UC report sometimes labeled them.

Contrary to these expectations, however, the UC scientists consistently invented devices of value in the ASW arena, and the immediate turnover of an embryonic concept was considered ill-advised. The compromise was for the Pacific lab to do some initial design and development and at some reasonable milestone ship it to the East Coast. (As will be seen in the next chapter, the UC technologists in actuality developed their ideas into prototypes, and finally into working models that went to sea.) After the ASW effort wound down, the devices division spent the last two years of the war developing pro-submarine sonar and countermeasures devices.

The third UCDWR scientific division was the Training Aids Division, which in its three areas of endeavor selected training techniques and methods, designed and developed training devices, and developed maintenance manuals for sailors who would operate the new sonar and related equipment under development.

California Institute of Technology

Unlike the University of California, assigned a specific set of responsibilities by the National Defense Research Committee and positioned by the Navy at an existing military laboratory, the California Institute of Technology had to work proactively to get into the war effort. That required it to offer its laboratories and scholarly personnel for whatever the nation might consider a reasonable endeavor, then to determine itself what that endeavor might be, and finally to search for an appropriate location to pursue it. This was a substantial shame for an institution of such prestige as Caltech, one of America's premier technology educators, one of only several volunteering its services for the First World War, and one with such distinguished professors and alumni. Nonplussed, it rose to the occasion.

Amos Gager Throop was a wealthy Chicago politician with high hopes of being elected mayor of the Windy City. His hopes relative to Chicago were dashed, but he was somewhat compensated for that when he was elected the third mayor of Pasadena, California, in 1888. Shortly after his term of office ended, in September 1891, Throop, a strong advocate of education, rented space in the

Wooster Block on the southeast corner of Fair Oaks and Green Street in his adopted city. A few months later, with six instructors and thirty students, he opened Throop University, a co-educational learning establishment for all ages. The following year he sought larger quarters, moving five or six blocks northwest, and the year after he changed the name to Throop Polytechnic Institute.

A decade later, the institute's fortunes advanced as George Ellery Hale joined the board of directors. An eminent astronomer, Hale at the time was beginning a two-decade stint as director of the Mount Wilson Observatory, which looked down on the city of Pasadena from an impressive site and height in the San Gabriel Mountains to the northeast. Championing major civic improvements like the Huntington Library, he also supported the evolution of Throop, most importantly suggesting concentration on an engineering discipline.

Critical among his accomplishments, Hale was substantially involved over several years in recruiting key academics to come to Pasadena, including renowned University of Chicago physicist (and later to be Noble Prize winner) Robert A. Millikan, who initially spent a few months a year at the school, lecturing in physics. (As did Albert Einstein, in the early 1930s. Millikan, on the other hand, served as the institute's president for a quarter of a century, disputing and generally disbelieving the theory of general relativity.) The school had moved to a large tract of land a short distance from downtown Pasadena in 1910, and three years later changed names again, this time to Throop College of Technology.

A quarter of a century before early World War II scientific efforts, officials of the college had spent substantial time in Washington, D.C., seeking to convince political and military leaders of the potential value of academic institutions in solving military problems attendant upon the First World War and recruiting scientists to solve them. Throop was one of the first of a fairly small number of academic institutions offering such scientists. The college's representatives advocated a trio of themes: the advancement of American science and technology, the advancement of the United States as a world leader in scientific achievement, and the advancement of Throop as a premier institution of higher learning. Although their World War I efforts gained little traction, they established an impressive network of contacts that would be invaluable to them in future years.

On February 10, 1920, the school changed names a third time, forsaking the founder for a title that resounded with the challenging ideals, hopes, and dreams of George Ellery Hale and Robert Millikan: California Institute of Technology.

Over the next several decades those hopes and dreams were more than realized as the institute (familiarly referred to as Caltech) advanced to a commanding position of leadership among the nation's science and engineering institutions. Internationally known scientists (among them Niels Bohr and Einstein) lectured there; Millikan received the 1923 Nobel Prize in physics, one of ten associated with the institute between the world wars who would eventually become Nobel laureates; and substantial funding built new classrooms and laboratories. Interestingly, all that funding was private; during his years at the university helm, Millikan was vocally opposed to government funding, believing the future of the nation lay in achievement in basic science. Instead, he sought foundation funding and increasingly private donations to support salaries, facilities, and research. One such foundation was the philanthropic vision of W.K. Kellogg of breakfast food fame; it would provide the university a renowned physics lab where Charles Lauritsen would gain substantial fame.[54]

The war years

As the world lost sight of any lessons learned during the latter half of the 1910s, George Hale's leadership during that challenging time came to the fore again, as Caltech stepped forward to offer its services in defense of the nation:

> The predisposition of CalTech to aid in the national defense is linked to George Ellery Hale, the World War I champion for scientific involvement in defense… This birthright of concern for the nation was retained in 1920 when Throop College became CalTech…. By September 1921, Hale and [Dr. Arthur A.] Noyes were successful in bringing Robert Millikan to CalTech where he became the chief executive. Millikan was unique among academic scientists in that he was among the few who had maintained a constant interest in the problem of improving defense through technology.[55]

---

[54] The preceding paragraphs of Caltech history were culled from the following sources: Judith Goodstein, "History of Caltech," published on-line: nobelprize.org, visited December 25-27, 2016; http://archives.caltech.edu/about/fastfacts.html, visited December 23, 2016; Christman, *Sailors, Scientists, and Rockets*; "Then and Now," California Institute of Technology Engineering and Science magazine, visited January 2, 2017 at https://eands.caltech.edu/then-and-now/.

[55] *Sailors, Scientists, and Rockets*, 80. The history of the rocket program at the California Institute of Technology and its transfer to and astounding success at a Navy laboratory is presented in painstaking detail in a series of volumes titled *History of the Naval Weapons*

Following in the footsteps of Hale, in May 1940, a trio of Caltech professors informally contacted fellow staff members to determine their willingness to apply their scientific skills to a war effort, should it become necessary. Within a few weeks they had a list of several hundred of their associates prepared for some form of partial or full-time commitment to such an effort. Organizing the California Institute of Technology (C.I.T.) Council on Defense Cooperation were Dr. Richard C. Tolman, Dr. Max Mason, and Dr. Earnest C. Watson. The latter had initiated the effort by approaching Tolman and Mason; he and Mason elected Tolman chair of the council. A "Report on the Possible Contributions of the California Institute of Technology to the Problem of National Defense" was developed, stating the institution was "ideally adapted to make such first scouting efforts [to develop potential ideas and inventions to support the war effort], and to carry on later, under Army or Navy support, those of proven promise."

One of the potential volunteer professors had been a faculty member for a decade and was directing the Kellogg Radiation Laboratory at the time. Dr. Charles Christian Lauritsen was introduced earlier in this chapter; his exceptional contributions to a nation at war will be detailed below and in succeeding chapters.

Also noteworthy among the volunteers was Linus Pauling, the only individual ever to win two unshared Nobel Prizes. On June 12, 1940, he wrote a letter to Tolman, expressing his thoughts on how the institute might be most useful to the country in the approaching crisis:

> I suggest that the type of problem which could most profitably be given for solution to the staff is that in which the problem itself is posed, but for which no solution has been found [or] perhaps even indicated. Problems of this general type could be attacked from all sides by a group of chosen men representing various fields of experience, with considerable hope of successful solution.[56]

Center, China Lake, California (Vols. 1 & 2) and *History of the Navy at China Lake, California* (Vols. 3 & 4). These volumes report extensively on the academic institution that was the unequivocal birth parent and originator of their laboratory, referring to it as "CalTech," while the educational entity titles itself "Caltech." This history will honor the institute by using its own version of the name except when quoting directly from the Navy history series.

[56] Letter from Linus Pauling to Richard C. Tolman, June 12, 1940, Ava Helen and Linus Pauling Papers, Oregon State University Libraries.

Aerial view of the campus of California Institute of Technology in the 1940s.

Before the report detailing the Caltech resources available to the cause, which included Pauling's statement, was even completed, Tolman had been called to Washington, D.C. by Vannevar Bush, head of the newly formed National Defense Research Committee. (Boasting an engineering doctorate awarded jointly by Harvard and the Massachusetts Institute of Technology, Bush was the former dean of the MIT School of Engineering. As will be detailed in the next chapter, he represented America's best hope for establishing an effective collaboration between the nation's potential military might and its technological superiority embodied in its universities.) Tolman, a chemist, cosmologist, and one of the few American scholars who fully understood Albert Einstein's theories (he wrote the definitive teaching thesis on "Relativity, Thermodynamics and Cosmology"), became vice chairman of the NDRC and chairman of its Division A, overseeing the development of armor and ordnance. During the war, he was also chief science advisor to General Leslie Groves, who directed the Manhattan Project.[57] Seeking known scientific expertise and perhaps a familiar face, he reached back to Caltech and asked Charles Lauritsen to join him as his division deputy. Lauritsen agreed.

Dr. Millikan, chairman of Caltech's Executive Council (what most universities call the president) from 1921 to 1945, both agreed and disagreed. He fervently agreed Lauritsen was a key asset in any endeavor to apply technology to military needs; he disagreed the place to accomplish that was on the East Coast.

The differing views of Tolman and Millikan represented a controversy originating in the World War I effort of Caltech (at the time still Throop College of Technology) and other educational institutions to offer scientific support to the country. Military and political leaders of the era had pushed to bring those volunteer scientists to the Washington area, essentially to gather intellectual resources into a common area where they could work together on the most significant challenges facing the armed services. Millikan, who had had experience with and had seen the failure of that philosophy during the first world war, also had parochial interests: he wanted Caltech to participate actively in the conflict visualized as approaching at significant speed, and Charles Lauritsen was his prime candidate for leading that effort. He would write Lauritsen repeatedly, urging him to come home and work in the national interests in Pasadena.[58] From a less institutional-centric point of view, he believed philosophically and perhaps metaphysically that a team of professors/scientists operating in familiar laboratories at home with known and trusted associates would produce superior results to a team composed of more brilliant technologists who had never worked together but now did by government edict. (A close analogy from years in the future and another area of endeavor might be the difference between the National Football League's Super Bowl champions and the winning team in the Pro Bowl.)

Lauritsen worked on every aspect of weapons development at NDRC for the better part of a year, but with his interest increasingly drawn to rockets. In April 1941, Robert Millikan's son, Dr. Clark Millikan, advised him of plans for a new anti-aircraft range in the Mojave Desert near Barstow, California.[59] Lauritsen received the news as he was preparing for a trip to London with an associate to investigate weapons research underway there. Although the Brits' anti-air rocket

---

[57] "Tolman Award," Southern California Section of the American Chemical Society, accessed January 2, 2015, http://scalacs.org/?page_id=20.

[58] *Sailors, Scientists, and Rockets*, 87.

[59] *Sailors*, 107.

program was having little effect on the nightly German bombing raids, Lauritsen was intrigued with the possibilities. When he returned to the States, he approached

OSRD chairman Vannevar Bush with a proposal for a broad expansion of the U.S. rocket program, offering Caltech as an obvious choice to pursue the effort.

Bush agreed, but requested Lauritsen first provide a written report on the status of rocket development, with appropriate recommendations on how to proceed. Lauritsen responded on August 1, 1941, with a three-thousand-word report relating the subject of rockets and concluding with six key questions that should be addressed in his proposed expansion of the U.S. rocket program.[60]

With Bush's approval, Lauritsen and Tolman flew back to Pasadena to confer with Caltech officials to ensure their willingness to support the effort. Tolman then wrote Bush a letter, which Lauritsen delivered in person, proposing expansion of their Division A program to develop anti-aircraft rockets and advising the institute was fully prepared to go into the rocket business. Shortly thereafter, OSRD responded with

> contracts to a number of firms and universities for weapon development. The two largest contracts to result from this decision were those with Caltech in the West and George Washington University in the East. These contracts marked a turning point in military rocket development, for they provided for the first time the means of securing the talents of adequate numbers of scientists and engineers to make a massive assault on the technical problems.[61]

Columbia University

The selection by OSRD of the University of California for its West Coast ASW lab essentially was mirrored by establishment of an East Coast lab to be managed by Columbia University, one of the oldest institutions of higher learning in the U.S. Founded in 1754 by royal charter of England's King George II as King's College, its first classes were conducted in July of that year for eight students in a new school building next to New York City's famed Trinity Church. After the Revolutionary War, during which instruction was suspended for eight years, classes resumed in 1784, under a new name, Columbia College.

[60] The full text appears as Appendix A in *Sailors, Scientists, and Rockets*, 253-259.
[61] *Sailors*, 113.

After steady growth, several physical moves, and a decision to concentrate curriculum in science and engineering, the institution moved to its present location in upper Manhattan in 1897 and received its current official title of Columbia University in the City of New York. A bequest from Joseph Pulitzer endowed the school of journalism in 1912; his prestigious Pulitzer Prize was established five years later, with the attendant competition administered by Columbia.

Operating under a contract substantially similar to that of the University of California, Columbia established its physical laboratory in New London, Connecticut. (While at first mention that appears a significant distance, the actual mileage from UCLA to Point Loma and from New York City to New London differs by only about ten miles.) As it had on Point Loma, the Navy constructed facilities for the university contractor at Fort Trumbull, completing the first building in July 1941.[62] From this building and other facilities, including laboratories at the university itself in New York City, scientists and engineers from and associated with Columbia conducted similar studies to those in California with the same general objectives: 1) to perform basic scientific research aimed at understanding the principles of underwater acoustics, and 2) to make use of their findings in developing technology to use those principles to locate enemy submarines, specifically German U-boats, so they could be destroyed.

Columbia University sound experiments included use of explosive sources at sea in both shallow and deep water off the East Coast of the U.S. in 1943 and 1944. Much of the research was summarized in the book *Propagation of Sound in the Ocean*.[63] Additionally, an in-depth discussion of the work conducted on the East Coast relative to anti-submarine warfare can be found in *Hellions of the Deep*.

As will be described in some detail relative to the University of California World War II work, the research and development activities at Columbia on behalf of NDRC and OSRD concluded with the various cessations of hostilities and signing of peace treaties in 1945. Also as occurred in California, however, the work was regarded as valuable enough to continue after the war. Several sources

---

[62] "The U.S. Navy Underwater Sound Lab," USL Document 85801 of 1 May 1948, 1. This Navy historical document indicates these efforts were conducted by an organization titled the Columbia University Division of War Research. The university's own extensive archives from the period state: "Originally called the Office of War Research, the name was changed after World War II to Division of Government Aided Research." Since the work conducted at Columbia is generally outside the scope of this history, we leave it to others to perform appropriate research to discover the truth about the title.

[63] Memoir 27 (New York: The Geological Society of America, 1948).

state the Navy consolidated the efforts of Columbia and similar efforts of the Harvard Underwater Sound Laboratory (summarized in the next section) and established the Navy Underwater Sound Laboratory in 1945.[64]

Again, the cited East Coast organizations are generally outside the purview of this history. However, for the sake of important evolutions to be discussed later in this history (see Volume II chapter on Base Closure and Realignment Commission actions of 1991), suffice it to say that the Underwater Sound Laboratory, whenever it was established, was combined organizationally with the Naval Underwater Weapons Research and Engineering Station at Newport, Rhode Island, in 1970 to form the Naval Underwater Systems Center. That organization was necessarily involved in the Base Closure and Realignment actions (BRAC '91) that established the Navy's four warfare centers in 1992. In 1996, the facility at Fort Trumbull was closed and activities were merged at Newport.

Harvard and MIT

As noted a number of times, the National Defense Research Committee (and its later overarching successor, Office of Scientific Research and Development) made substantial use of university faculties and laboratories to prosecute various technologies to assist the military in defending the nation during World War II. The establishment of the East and West Coast submarine defense laboratories required extensive personnel recruitment to staff and operate those labs.

In a separate effort, a group had been formed at the Massachusetts Institute of Technology (MIT), based on a Navy's Bureau of Ships contract, to conduct underwater sound measurements aimed ultimately at defeating German acoustic mines. During nation-wide recruiting for the East and West Coast submarine labs,

[64] Cathy Ann Clark, "The Sound Lab at Fort Trumbull, New London, Connecticut 1945-1996," *Journal of the Acoustic Society of America*, published online: April 2015. Interestingly, both the University of California Division of War Research biweekly reports and the U.S. Navy Radio and Sound Laboratory's first biweekly report to the Chief of the Bureau of Ships on March 6, 1943 clearly included USNUSL New London on their copy lists. In a telephone call with Tom LaPuzza March 7, 2017, John Woodhouse of the NUWC Newport Public Affairs Office confirmed the consolidation of CUDWR and HUSL in 1945 is cited officially as the establishment of the Navy Underwater Sound Laboratory.

the MIT group was made aware of this initiative and proposed to NDRC to divert some of its resources to support the study of sub-surface warfare, specifically at the Columbia University lab in New London. A formal proposal to that effect, specifying Harvard University as the responsible institution, was forwarded to NDRC, and a contract was signed, under which Harvard personnel, directed by Dr. Frederick Hunt, "undertook research on certain aspects of submarine detection by means of sound. A research program was planned which would attack this general problem from two points of view: first, improvement of existing equipment; second, design of new equipment."[65] (In a manner closely paralleling those of Charles Lauritsen at Caltech and Vern Knudsen and Ralph Christensen at UCLA, Dr. Frederick [Ted] Hunt was a Harvard professor who departed the classroom to support the war effort with his scientific expertise, which was extensive and, much like that of the latter two, focused on underwater acoustics.) The following year, on July 1, 1942, the name Harvard Underwater Sound Laboratory was officially applied to the group working on equipment development. Although that work is outside the scope of this history, it is significant to note: "The word SONAR did not exist. In early 1941, a Range/bearing display scheme was dubbed CRAB. Hunt shortly thereafter coined the term SONAR for SONic, Azimuth and Range. The Navy changed the definition to SOund NAvigation and Ranging. Hunt was admittedly trying to make an easily understood term similar to RADAR."[66]

As the world settled down to the serious business of conducting a war unprecedented in its multi-millennia history, our story will focus on the four entities described: U.S. Navy Radio and Sound Laboratory, University of California Division of War Research, California Institute of Technology, and U.S. Naval Ordnance Test Station. In succeeding chapters, we will explore how those organizations evolved and grew to provide technologies critical to the Navy.

---

[65] Frederick V. Hunt, "Establishment and Objectives of the Harvard University Underwater Sound Laboratory," 2.

[66] Frederick M. Pestorius, David T. Blackstock, "Contributions to the development of underwater acoustics at the Harvard Underwater Sound Lab," *Journal of the Acoustical Society of America*, Vol. 137, Issue 4, April 2015, 2274. Pestorius commanded the Point Loma laboratory from 1984 to 1986. He had earned his master's degree from Harvard in 1964, studying under Hunt, and remarked, "I never realized during my two years at Harvard with Hunt what a huge contribution he had made, as a young professor, to our war effort. The enduring legacy of those labs is the architecture of modern submarine sonar systems, even with all the impact that digital technology has had on the functional level. Hunt was the primary architect." (Mike Pestorius email to Tom LaPuzza, December 21, 2016).

Dr. Frederick V. Hunt

Leo P. Delsasso

Leo Delsasso spent almost the entirety of his life at the University of California, beginning as a freshman in 1919 in a brand-new department (physics) at the brand-new Southern Branch of the university. The branch's first campus was on Vermont Avenue, where the physics department had one professor.

Delsasso arrived at the university after a World War I tour with the Navy. While attending his first classes, he maintained his Navy Reserve status, inventing an acoustical depth sounder for surface ships. He was assigned temporary duty on USS *Maryland* (BB-46) to supervise installation and operation of the sounder as the battleship cruised from Honolulu to Sydney, Australia. The device provided ocean-depth display throughout the cruise, an important pioneering feat in depth sounders.

In January 1941, Lieutenant Leo Delsasso, U.S. Naval Reserve, was called up to active duty. He took leave from the university and traveled south to Point Loma, where he would spend the duration of the war at the Navy Radio and Sound Lab.

As assistant to the Physics Department chairman starting his second year, Delsasso constructed most of the laboratory instruments used in the first physics classes at the Southern Branch. He graduated in 1925 and returned in the fall as a physics instructor. In addition to classroom work, he invented several acoustic range-finding devices for ships and airplanes.[67]

Two of the very early principals at the Point Loma site were Dr. Leo P. Delsasso (left), a Naval Reservist assigned to NRSL, and Dr. Vern O. Knudsen, first head of UCDWR. Both long-time leaders in the Physics Department at UCLA, they are shown in Knudsen's office decades after the war.

In reviewing the second and third NRSL formal technical reports, he would

[67] *Popular Science Monthly*, January 1930, 41, and *Popular Mechanics*, June 1936, 141.

be listed as the "Technical Aide." Promoted to lieutenant commander in the summer, He received his doctorate from California Institute of Technology on June 13,[68] and shortly afterward became the NRSL assistant director. Since the director would change several times in the course of the war, the corporate memory would be maintained by Leo Delsasso.

In 1946 he hung up his uniform for the final time, retiring from the reserves with the rank of commander, and returned to UCLA.[69] After serving as assistant and associate dean of the university's Graduate Division, Delsasso was appointed chairman of the Department of Physics in 1959. He retired four years later and was named professor emeritus, but he continued his own research, and particularly assisted others with their research until his death in July 1971. He died boarding a train in Frankfurt, Germany, on his way to the Seventh International Congress on Acoustics, where he was scheduled to present three papers he'd completed at UCLA during the past three years. At the time, he had been associated with the university—as a student, instrument maker, instructor, professor, dean, scholar, and most essentially mentor—for fifty-three years.

---

[68] California Institute of Technology Commencement Program, June 13, 1941; http://www.caltechcampuspubs.library.caltech.edu/2548/1/June_13%c_1941.pdf, visited March 13, 2017. His thesis title was "The Measurement of Altitude and Inclination of Aircraft by the Echo Method." Dr. Delsasso essentially adapted sonar principles to furnish airplane pilots data on elevation and inclination with respect to the ground, plus notification of nearby hazardous terrain such as mountains.

[69] University of California *Calisphere Obituary*: Leo P. Delsasso, Physics; Los Angeles.

2

The War Approaches America

The year was 1939. In Europe and Asia, the distressingly efficient war machines of Germany and Japan were shifting into high gear, roaring into neighboring countries and steamrolling them into submission. Although the United States was not yet at war, Americans knew they were likely to be drawn into the global conflict. On September 3, hours after the European conflict officially commenced with declarations of war by Britain and France, the German submarine *U-30* torpedoed the British passenger liner *Athenia*, bound from Glasgow to Montreal with 1,103 aboard, 311 of them Americans. Twenty-eight of those Americans were among the 112 who perished in the sinking.

As tank, artillery, and infantry battles raged across the landmass of Europe, Allied fleets and merchant shipping suffered terrible losses at sea from German *unterseeboote*. As British Prime Minister Winston Churchill described it,

> The U-boats now began to use new methods, which became known as 'wolf-pack' tactics. These consisted of attacks from different directions by several U-boats working together. Attacks were at this time usually made by night, the U-boats operating on the surface at full speed unless detected in the approach. Under these conditions only the destroyers could rapidly overhaul them.[1]

Royal Navy and British merchant ships departed Canadian ports in convoys in a desperate attempt to keep the isolated island kingdom supplied, but German submarines, equally determined to choke the life out of that island kingdom, sank three million tons of Allied shipping in the last six months of 1940. In one of the most significant of those incidents, a mass of U-boats attacked the convoys SC-7

[1] Winston S. Churchill, *World War II, Volume 3: The Grand Alliance* (Boston: Houghton Mifflin Company, 1950), 126.

and HX79 for three nights between October 16 and 19, 1940. When "The Night of the Long Knives" was over, thirty-four ships had been sunk.[2]

Magnifying the menace posed by the U-boats was their tactic, explained by Waldo Lyon three decades later:

> … we were… also attempting to understand some of the problems that the east coast of Canada was facing with the German submarines in the Gulf of St. Lawrence because that is the same cold-water situation where a submarine can hide underneath temperature layers that are formed by these cold waters… a submarine can lie near the surface or just below a temperature layer and cannot be detected by surface craft... the Germans made very effective use of this layer in their attacks on the shipping that came out of the St. Lawrence.[3]

Thus, even before the convoys reached the open waters of the Atlantic, U-boats attacked them at will. Churchill lamented two shortcomings of the Royal Navy: the fact that in high-speed night attacks "the Asdic[4] was virtually impotent," and lack of an air-dropped weapon that could be used to exploit the vulnerability of a submarine on the surface. Failure to recognize the seriousness of the threat and respond earlier was unfortunate, because

> Now, when the full fury of the storm broke, we lacked the scientific equipment equal to our needs. We addressed ourselves vigorously to this problem, and by the unsparing efforts of the scientists, supported by the solid teamwork of sailors and airmen, good progress was made.[5]

The British reaction to the critical necessity of addressing the U-boat menace (heroic efforts by scientists and military personnel working together) constituted a significant parallel to the short- and long-term efforts of the two California Navy laboratories on the identical necessities of locating enemy submarines and attacking them from the air.

In addition to relying on his own resources, Churchill appealed repeatedly for assistance from the United States. In response, attempting to maintain neutrality, President Franklin D. Roosevelt signed an agreement September 2, 1940, to trade more than fifty older Navy destroyers to Britain in exchange for ninety-nine-year

---

[2] www.uboataces.com/tactics-wolfpack.shtml accessed January 21, 2017.

[3] *The Reminiscences of Dr. Waldo K. Lyon*, 7-8.

[4] Acronym for Anti-Submarine Detection Investigation Committee, one of the earliest versions of what later came to be known as sonar, designed by British, French, and American scientists during World War I. The Brits subsequently made some improvements on it. See: http://boat.net/allies/technical/asdic.htm visited March 3, 2017. See also: *Hellions of the Deep*, 8 & 60.

[5] *The Grand Alliance*, 126.

leases to land in Newfoundland and the Caribbean. Popularly known as "Lend-Lease," this and subsequent agreements enabled Britain to fight the U-boat threat more vigorously and to replenish its supplies.[6]

The toll from German submarines nevertheless mounted. In the month of June 1941, more than a half million tons of Allied shipping were lost to U-boat attacks. In July, Roosevelt announced U.S. warships would protect American merchant vessels in the North Atlantic. Without a declaration of war, the U.S. Navy was effectively engaged in the fight. A few months later, on Halloween 1941, it would suffer its first naval loss of the war, when the *U-552* torpedoed the destroyer USS *Reuben James* (DD-245), killing 115 sailors and officers. While the presence of U.S. warships might have provided some better feeling of safety to the civilian freighters attempting to the cross the Atlantic, their actual effectiveness was minimal at first. In January 1942, Hitler set in motion Operation Drumbeat, ordering concentrated submarine attacks on American and British merchant ships carrying war material.[7] Over the next three months, more than a million tons of material desperately needed in Europe were sent to the bottom of the sea.

Centuries of undersea interest

U-30, *U-552*, and the "Long Knife" U-boats were at the time merely the latest products in decades of German technology development related to undersea craft and long-term interest around the world in employing the undersea environment for a key element lacking in sea battles—surprise. Centuries before the invention of radar, surface ship look-outs—whether on three-masted schooners, ironclads, or steam-driven, armor-plated dreadnoughts—could spot an enemy ship in sufficient time to alert their shipmates to prepare sword and cutlass, twelve-pounders, or sixteen-inch guns long before the approaching enemy could fire a single round. The element of surprise that had been a significant factor in battles on land was of no account in battles at sea.

---

[6] "Lend-Lease and Military Aid to the Allies in the Early Years of World War II," Office of the Historian, U.S. Department of State.

[7] Jason Fagone, *The Woman Who Smashed Codes* (NY: Harper Collins Publishers, Inc., 2017), 242.

Generations of mariners, inventors, and storytellers had dreamed of navigating *under* the sea, safe from enemies and surface storms, stealthily carrying powerful weapons to the scene of an ensuing battle without the slightest realization on the part of the enemy a battle was ensuing, let alone imminent. Rising to the surface with absolute surprise, they could unleash those weapons with impunity and immediately dive to avoid damage or casualties and to fight another day, virtually unchallenged.

Artists and writers portrayed in substantial detail what naval officers could only dream of: Leonardo da Vinci sketched a submarine in his notebooks and imagined his stealthy craft destroying the Turkish ships that threatened Venice.[8] Jules Verne's popular 1870 novel *20,000 Leagues Under the Sea* told the remarkably prescient story of the scientist-engineer Captain Nemo roaming the world's ocean depths in his submarine *Nautilus*.

Turtle

But amid what appeared fantastic fantasy lurked imaginers of a different sort: those seeking to instill reality into those fantasies. David Bushnell, a Connecticut inventor, devised and built the first practical submarine, *Turtle*, between 1771 and 1775. With a spherical hull of wooden staves and iron hoops (which Bushnell likened to "two upper turtle shells of equal size, joined together"), the clumsy craft possessed the four capabilities necessary for any military submarine: to submerge, to propel itself and maneuver, to keep its crew alive underwater, and to carry out operations against an enemy.

The intent of *Turtle* was to approach an enemy ship and affix an explosive charge to the hull. Navigational issues, tides, and ultimately, the physical demands of a human-powered submarine frustrated *Turtle*'s three attempts to sink British warships, but she floated and traveled underwater, and the concept was promising enough that, ten years later, George Washington wrote Thomas Jefferson: "I then thought, and still think, that it was an effort of genius."[9]

---

[8] http://www.leonardo-history.com/inventor.htm.
[9] Letter from George Washington to Thomas Jefferson, Sept. 16, 1785.

CSS *Hunley*

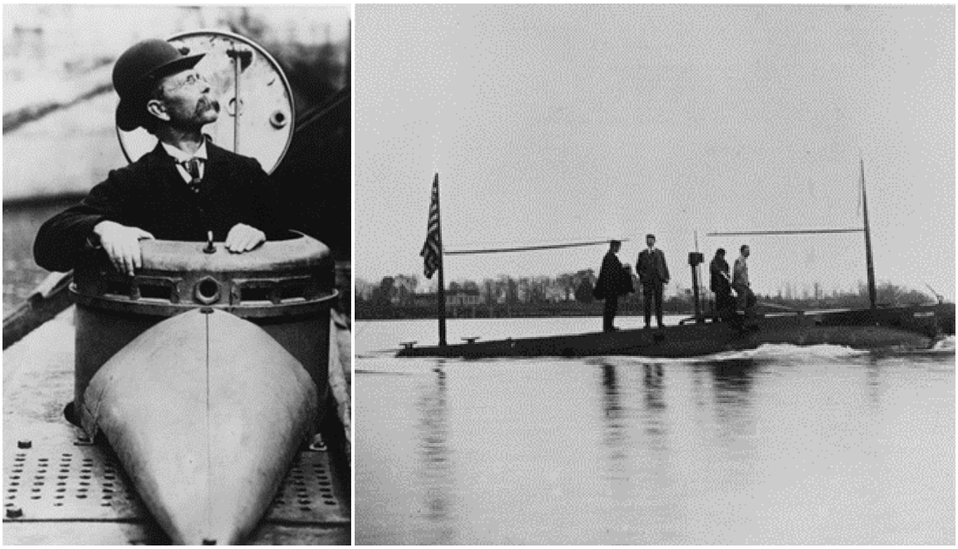
The American Civil War provided an opportunity for what a century later would be labeled "asymmetric warfare." New Orleans businessman Horace L. Hunley understood substantially better than his fellow Confederates that continued commerce with the Continent, especially England, offered the only possibility the rash action of seceding from a decidedly more powerful Union could succeed. The superior naval forces of the North blockaded many of the South's essential ports, slowing and then effectively stopping that commerce.

Attempting to ease the stranglehold of port blockades, Hunley provided financial support to steam gauge manufacturers and inventors James McClintock and Baxter Watson to develop an underwater craft. Hunley's funds and the ingenuity of McClintock and Watson produced three such craft, the third named for the financier. *H.L. Hunley* was fabricated in Mobile, Alabama, and transported via railroad flat cars to the major Confederate port of Charleston, South Carolina.

On the night of August 29, 1863, with Lieutenant John A. Payne in command and a crew of eight volunteers turning the long camshaft that ran the length of the forty-foot craft to provide propulsion, the sub got underway, but immediately sank. With fore and aft hatchways slightly larger than a foot in diameter, only four of the crew, including the lieutenant, were able to get out alive.

Six weeks later, with another crew and Hunley himself aboard, the sub ventured away from the dock on a routine dive prior to attacking the Union blockade. The craft dove normally, but failed to return to the surface. When the sub was subsequently found, jutting at a sharp angle from the mud floor of the harbor, the commander of the Charleston defensive forces decided to abandon the idea. One of his junior officers, Lieutenant George E. Dixon, however, convinced him to allow one last effort. *Hunley* was raised, re-outfitted, and armed with a 135-pound torpedo on the end of a seventeen-foot-long metal spar extending from the sub's bow. With Lieutenant Dixon commanding, the sub left the dock on the night of February 17, 1864, first on the surface and then a few feet underwater. *Hunley* rammed the U.S. Navy ship *Housatonic* with the spar, depositing the torpedo and backing away to tighten the detonation rope. At a distance of 150 feet, the taut rope triggered torpedo explosion, and *Housatonic* erupted in fire before sinking.

Hunley surfaced and signaled forces ashore the mission was a success, but never returned. For almost a century and a half, the fate of the first submarine to attack an enemy ship successfully remained a mystery.[10] After numerous attempts, some spurred by an offered reward of $100,000, the *Hunley* wreck was located in 1995 and raised in August 2000. It may be seen in Charleston.[11]



John Holland, after several years attempting to sell his submarine concept to the U.S. Navy, won the first competition by that Navy to develop a sub. The successful result was SS-1, later named USS *Holland*, shown underway in Long Island Sound.

Navy sponsors submarine competition

The U.S. Navy demonstrated sufficient belief in the promise of submarines that it held a design competition in 1888. Irish-born John Holland, who since 1875 had attempted to interest the Navy in his ideas on such vessels, won the competition. After several unsatisfactory models, he built a boat on propulsion

[10] Preceding paragraphs based on "Friends of the Hunley," http://hunley.org.
[11] "Submarine Development," Naval Historical and Heritage Command, http://www.history.navy.mil/branches/teach/dive/hist1.htm .

principles that would become standard for more than fifty years: a liquid-fueled engine (in this case, gasoline) would drive the propeller for surface travel and simultaneously drive a generator to charge the batteries needed to fuel an electric motor for underwater propulsion. In October 1900, USS *Holland* (SS-1) joined the fleet.

In 1909, gasoline gave way to safer and more efficient diesel fuel, and a generation of submarines suitable for underwater warfare began operating in the world's navies. Planned uses such as harbor defense and striking ships at anchor emphasized stealth and minimized the problem of range.

A year later, two of the Navy's earliest submarines arrived in San Diego. The submarine torpedo boats *Grampus* and *Pike* steamed 560 miles from Mare Island to San Diego (a record distance for subs at the time), arriving June 28, 1910. Moored near the ferry landing on Coronado, the subs were a local sensation, with the press calling them "demon divers" and "war demons." And for the local citizenry, "these small ships that could cruise under water represented nothing less than a marvel."[12] The public interest in observing them was occasionally so intense it interfered with their operations.

The subs conducted maneuvers in and around San Diego harbor for two years. During the second year, they tied up at a pier at the Naval Coaling Station on Point Loma to evaluate the site as a major naval operational base. (This initial evaluation was rather negative, although later history would demonstrate the location was a good one, not only for the operators but for a Navy laboratory as well.)

The timing drama was reminiscent of a Hollywood movie:

> Before their departure northward on 31 May 1912 to Mare Island, the crews of Grampus and Pike stood on their slippery decks and witnessed a momentous historic event—the very first flights of Glenn Curtiss' hydroaeroplane in San Diego Bay and the birth of United States naval aviation… It was a riveting and intriguing intersection of history where one, at a single moment in time, could observe the beginnings of the two most important naval warfare breakthroughs of the twentieth century.[13]

---

[12] Captain Bruce Linder, USN (Ret.) and Captain Thomas E. Ishee, USN, "Submarines in San Diego: The Early Years," *Mains'l Haul, A Journal of Pacific Maritime History,* Vol. 50: 3 & 4, Summer/Fall 2014, 18.
[13] "Submarines in San Diego," 18.

For the next five years, Pacific-based submarines shuttled back and forth between San Diego and San Pedro, with the latter getting the nod (and World War I construction funds) for home base in 1917. Over the next decade, however, it became increasingly clear the Navy's Eastern Pacific fleet of battleships, surface ships, submarines, and auxiliaries could not all be accommodated by the facilities in San Pedro, and in 1928 the Navy moved all of its West Coast subs to San Diego.

America's undersea fleet

American submarines, based on German U-boat designs from 1918, progressed slowly through the 1920s, culminating in the 385-foot leviathans called V-class boats. These had better range and heavier armaments than the earlier S-class boats, but sacrificed stealth and speed. In 1934, a new design, its vessels no longer lettered but designated by the name of the first boat in each class (for example, *Porpoise*, *Salmon*, and *Tambor* class boats) took advantage of better diesel engines and numerous upgraded systems, from armament to wiring. This 300-foot, 1,500-ton design was America's first real blue-ocean fleet boat, capable of 10,000-mile deployments, and by the outset of the Second World War, an intense shipbuilding program had increased the number of submarines in the Pacific to fifty-six. The new fleet boats were reliable and tough, armed with twenty-four torpedoes and four deck guns. They typically carried a crew of six officers and sixty enlisted men. They could dive to periscope depth of sixty-three feet in a minute, cruise underwater for as long as seventy-two hours, and were rated to dive to 300 feet.[14]

When the Navy sited its first West Coast laboratory on Point Loma in 1940, and the National Defense Research Committee positioned its University of California contract lab there less than a year later, both organizations required substantial submarine support for their research and development efforts. That assistance was located just minutes away at the bottom of the east-facing slopes of Point Loma.

The dominating undersea threat represented by the German World War II submarine fleet traces its origins from the late 1800s to the early 1900s.

[14] Keith Wheeler, *War Under the Pacific* (Chicago: Time-Life Books, 1980), 36-39.

Capitalizing on advancements of others (John Holland's liquid-fueled engine and the gas-electric power train and innovative double-hull of an inner, rounded pressure hull and a sleeker outer one of the *Narval*, designed for the French government by Maxine Laubeuf in 1896),[15] Germany produced its first modern U-boat by 1906. Although battleships were the centerpieces of the High Seas Fleet, by 1910 German shipyards had also produced a technically advanced submarine model. *U-19* had twin diesel engines, two bow and two stern torpedo tubes, and a cruising range of 7,600 nautical miles.

When Britain declared war on Germany early in August 1914, it deployed its surface ships to blockade German ports, substantially reducing essential shipping and seriously jeopardizing the German empire. After a brief period of moral and ethical debate, Germany responded by putting to sea its several dozen existing submarines (dozens more were under construction at the time) under the terms of "unrestricted warfare."[16]

By late 1915, Germany was sinking a monthly average of 100,000 tons of shipping. The United States threatened to break off relations with Germany unless the attacks ceased. Germany pledged to stop, but unrestricted submarine warfare resumed in January 1917. Three months later, the U.S. declared war.

American submarine operation in World War I was largely restricted to anti-submarine patrols along the U.S. East Coast, where a new, long-range class of U-boats attacked Allied shipping and laid mines. Destroyers, depth charges, and mines led the fight against German raiders, however, and only eighteen of 178 U-boats destroyed during the war were sunk by Allied submarines.[17] One of those eighteen was the *UB-68*, commanded by Karl Doenitz, who spent the last few months of the war in a British prisoner of war camp. He returned to a defeated Germany with some novel military tactics developed during his imprisonment.

---

[15] Paul Akermann, *Encyclopaedia of British Submarines*, 1901-1955 (Cornwall, UK: Periscope Publishing Ltd., 2002), 1.

[16] International law at the time allowed a warship to stop and search a merchantman, and if contraband was found, to seize it and put aboard a "prize crew" to navigate to some appropriate port. As long as the safety of the captured ship's crew was secured, the merchant ship could be sunk. "Unrestricted submarine warfare," which Germany chose after some internal debate, meant a merchant ship could be sunk with no warning and no providing for the safety of the crew.

[17] "The School of War," *Undersea Warfare*, Spring 2004.

The Treaty of Versailles that ended World War I barred Germany from possessing U-boats, but little attention was paid to that stipulation. As German military might asserted itself again in the early 1930s, newer and more capable U-boats were constructed. In March 1935, Adolf Hitler renounced the treaty, and Karl Doenitz was selected to command the only existing U-boat flotilla, in effect making him the national submarine force commander. Within four years, Germany had fifty-seven U-boats at sea and accelerated their production through the war, ultimately commissioning 1,153 between 1935 and 1945.[18] The German U-boat threat, initially a terrifying surprise to the Allies, had been well-planned and executed by Germany, with particular credit for its success going to Doenitz:

> In four years of untiring and in the fullest sense of the word uninterrupted work of training, he [Doenitz] succeeds in developing the young U-boat arm, personnel, and material till it is a weapon of a striking power unexpected even by the experts. More than three million gross tons of sunken enemy shipping in only one year achieved with only a few boats speaks better than words of the services of this man.[19]

Particularly worrisome to the Allies were the "wolf pack" tactics Doenitz had developed during his time as a prisoner of war. While the underwater approach of a submarine provided it the element of surprise, the rudimentary state of sonar-like equipment also vastly reduced the submariner's ability to locate and target its prey. To remedy that, U-boats gathered on the surface in the dark of night, launching their torpedoes at the target from several directions, with devastating effect. Those torpedoes, like the vessels that carried them, had a lengthy developmental history.

Deadly fish

When Admiral David Farragut thundered, "Damn the torpedoes!" at the Battle of Mobile Bay in August 1864, he referred to anchored explosive devices today called mines. Devices called "spar torpedoes" were containers of explosives

---

[18] Commander Michael Thomas Poirier, USN, "Results of the German and American Submarine Campaigns of World War II," Chief of Naval Operations, Submarine Warfare Division, http://www.navy.mil/navydata/cno/n87/history/wwii-campaigns.html. Also John Vinocur, "War Veterans Come to Bury, and to Praise, Doenitz," *The New York Times*, Jan. 7, 1981.

[19] Extract from the official Nazi publication "Das Archiv," published 27 September 1940 upon promotion of Karl Doenitz to vice admiral.

carried on a long pole of wood or metal in front of a submerged or semi-submerged vessel. David Bushnell's *Turtle* employed such a weapon, unsuccessfully, as did the Confederacy's *H.L. Hunley*, much more effectively.

The first self-propelled explosive used by surface and underwater ships as a weapon of war was designed by British-born engineer Robert Whitehead for the Austrian Navy in 1866. Driven by a two-cylinder, compressed-air engine and carrying up to sixty pounds of explosive, three generations of Whitehead "automobile" torpedoes were purchased by navies around the world. The U.S. Navy declined to buy them, instead fabricating similar torpedoes at the Naval Torpedo Station on Goat Island in Newport, Rhode Island. Its initial designs failed.

Beginning in 1870, U.S. Navy Lieutenant Commander John A. Howell designed a flywheel-driven torpedo (the flywheel was set in motion on the launcher, then drove the torpedo's propeller upon release). The Navy purchased fifty, which remained its entire torpedo arsenal until 1896, when the U.S. finally joined the other large navies who were customers of Whitehead and Bliss-Leavitt, a company making torpedoes of a similar design.

Center-trained mine-hunting dolphins training in San Diego harbor in 2013 reported a target where none had been placed. Investigation and recovery revealed a Howell Mark 1 torpedo, lost from USS *Iowa* (BB-4) December 20, 1899.

The basic Whitehead design, and its successors through World War I, incorporated the essential components of torpedoes for generations: a self-contained propulsion system, a warhead, a detonation device, and a set of navigation technologies. In particular, Whitehead installed gyroscopic devices and depth navigation, enabling a fired torpedo to run true to its target. Range increased with size and payload.

In the early 1920s, the Navy returned to Newport to produce American-made torpedoes in versions that could be launched from surface ships, submarines, and from the air. The steam-driven Mark 13, the Navy's air-launched torpedo at the outset of World War II, achieved this, but in combat it possessed serious flaws. Those flaws, which basically consisted of explosions on water impact or non-explosions upon target contact, will be discussed in some detail in Chapter 4, as will the remedy developed by one of the California Navy labs.

As should be obvious, the German navy had no such problems with its torpedoes, particularly those carried by U-boats. Time and again, a single torpedo, launched underwater and seen too late, if at all, sent a luxury liner carrying hundreds of non-combatant passengers or a merchant ship with thousands of tons of desperately needed food and material to the bottom of the Atlantic.

Whether by the invisibility of submarines or the undeniable presence of massive tanks, the leadership and military acumen of Doenitz and his Army contemporaries like the Desert Fox, Erwin Rommel, put Germany in a world-conquering position that probably had not its equal in recorded history. Doenitz, in recognition of his contributions to that effort, was promoted to Grand Admiral, in charge of the entire German fleet, on January 30, 1943. He would eventually head the German state in its final days.[20] To halt the relentless advance of German submarines, ships, airplanes, tanks, and military personnel, America and its allies would require substantially more than military personnel, materiel, and platforms. Science, and individuals who could command people and technologists who understood that science, were required to save the day. One of the foremost of those was Vannevar Bush.

[20] http://www.jewishvirtuallibrary.org/nuremberg-trial-defendants-karl-doenitz visited February 20, 2017.

Vannevar Bush, technology leader

Dr. Vannevar Bush was a brilliant, impatient, and driven man. Holder of a doctorate in engineering jointly awarded by Harvard and MIT, former dean of the MIT School of Engineering, founder of the Raytheon Corporation, and former president of the Carnegie Institute of Washington, Bush was perhaps the most influential American scientist of World War II—less for his technical brilliance than for his administrative excellence, foresight, and will. Concerned about the gulf of ignorance between military and scientific communities of the 1930s, Bush approached President Franklin D. Roosevelt through the latter's uncle, Frederic Delano. On June 27, 1940, armed with a one-page proposal, Bush persuaded the president in fifteen minutes to approve the establishment of a new federal agency, the National Defense Research Committee (NDRC), with himself as its chairman.[21] The spirit of unity that would characterize the nation later, when it was actually at war, had not surfaced yet, and critics questioned the decision.

Many years later, Bush candidly admitted some of those critics were correct:

> There are those who protested that the action of setting up the NDRC was an end run, a grab by which a small company of scientists and engineers, acting outside established channels, got hold of the authority and money for the program of developing new weapons. That, in fact, is exactly what it was.[22]

Financed through the president's emergency funds, Bush gathered an executive team of university presidents, senior military officers, and government officials and established five broad divisions for the committee's focus and action: armor and ordnance; bombs, fuels, gases, chemical problems; communication and transportation; detection, controls, instruments; and patents and inventions. Bush selected Dr. Richard Tolman, who had led the California Institute of Technology Council on Defense Cooperation, as the vice chair of NDRC, and asked him as well to direct the committee's Division A, Armor and Ordnance.

Less than three months after Bush's initial visit to the president resulted in formation of a technology organization essential to national survival, Roosevelt

---

[21] G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (New York: The Free Press, 1997), 104-112.
[22] Vannevar Bush, *Pieces of the Action* (N.Y.: Morrow, 1970), 31-32.

continued the country's precautionary steps should war prove unavoidable by signing the Selective Service Act of 1940. In so doing, he declared,

> America stands at the crossroads of its destiny. Time and distance have been shortened. A few weeks have seen great nations fall. We cannot remain indifferent to the philosophy of force now rampant in the world. The terrible fate of nations whose weakness invited attack is too well known to us all. We must and will marshal our great potential strength to fend off war…Offers of service have flooded in from patriotic citizens in every part of the nation, who ask only what they can do to help.[23]

Faced with the reality of the world situation and the president's signing of the draft bill, farmers, factory workers, physicians, graduate students—people of every profession and region—considered what their role would be in the war that seemed inevitable. In the universities, military industries, and private laboratories, scientists, engineers, and technicians contemplated how they might turn their special talents toward the looming national emergency. Vannevar Bush's leadership would focus those talents where they would be most effective.

Growing fast from its inception, NDRC began apportioning scientific war work among numerous centers and laboratories in the U.S. The latter included existing military laboratories and the many universities that individually sponsored "defense committees" of various descriptions to offer technical expertise for strengthening the nation's defensive posture in a regrettably short amount of time.

Soon a protocol was worked out between NDRC and the military, which was drafting and quickly training tens of thousands of uniformed personnel and overseeing a rapid rearmament that allowed no time (or vision) for developing new weapons: NDRC would focus on scientific discovery and technological applications of discoveries, and the armed forces would handle the manufacture and deployment of military hardware. In practice, this meant Bush's organization tapped the resources of universities and private laboratories, while the Navy and Army worked with industry to manufacture arms.

One of NDRC's significant actions, in terms of this history, was collaboration with the Navy in the establishment of the ASW laboratories on April 26, 1941—the University of California Division of National Defense Research, subsequently Division of War Research, and Columbia University Division of War Research.

---

[23] Franklin D. Roosevelt, Proclamation 2425 - Selective Service Registration, Sept. 16, 1940.

In his report to the president on the first year of committee operation, Bush paid special attention to anti-submarine technology, mentioning the lab:

> The supersonic device is excellent when it works. Unfortunately, under certain conditions of the water, it works with extreme difficulty or not at all. This occurs when the water is much disturbed by propellors [sic], or especially by depth charges; but it also occurs when the temperature gradients in the water are severe…About two months ago the Navy requested the Committee to greatly enlarge its anti-submarine investigations. Accordingly, scientific groups are starting work in connection with two new Navy stations for anti-submarine investigations, at New London and San Diego…where many new lines of research are being started.[24]

OSRD replaces NDRC

As Bush was developing his report, one of his committee's key leaders, Dr. James Conant, was lunching with President Roosevelt, discussing his recent visit to Great Britain to establish a liaison office. He reminded Roosevelt of "the need of an Office of Research and Development for liaison purposes with the War and Navy Department."[25] He provided a notional organization chart, with three entities reporting directly to the president—Secretary of War, Secretary of the Navy, and OEM (Office of Emergency Management)—with the new Office of Research and Development headed by Bush under OEM. There would be a London office "for general exchange of information with British on research and development,"[26] essentially what Conant had gone to England to set up.

Conant's stated thought on the Office of Research and Development was: "I have put in Dr. Bush's name as Director, as all of us who have been in contact with him feel that he is the one man who could undertake this difficult task."

On June 28, 1941, the day of Bush's report to the President, FDR signed the paperwork to set up the slightly retitled Office of *Scientific* Research and Development (OSRD), with Dr. Bush as chairman. Dr. Conant assumed leadership of NDRC, which became an advisory unit of the OSRD. The new

---

[24] Vannevar Bush, "Report of the War Research Committee for the First Year of Operation," FDR Library, June 28, 1941, 28-29.
[25] Dr. James B. Conant letter to President Franklin Roosevelt, April 25, 1941, 1. Conant at that time was the president of Harvard University, a position he held from 1933 until 1953.
[26] Conant letter to FDR, 3.

organization enabled Bush to proceed with weapons research and production without awaiting approval from the military for individual programs.[27]

In addition to the liaison with the U.S. military and with the British, there were other issues which the president's second executive order settled:

> The NDRC, however, had neither the authority nor the funds to carry research forward into development and production. Concerned that the NDRC needed additional support, President Roosevelt issued Executive Order 8807 on June 28, 1941 establishing the Office of Scientific Research and Development as an independent entity within the Office for Emergency Management. Vannevar Bush was … given the authority to enter into contracts and agreements for studies, experimental investigations and reports.[28]

In his new position, Dr. Bush wrote a letter of intent on July 24, 1941, justifying the expenditures the University of California had already made. His staff followed up quickly with legal documentation, as contract OEMsr-30 between OSRD and the University of California was executed on August 15, retroactive to April 26. That paperwork covered previous commitments made by the university since the UC Division of National Defense Research establishment. Contract terms provided "the Contractor would equip, staff and operate a laboratory for studies and experimental investigations in connection with and for the development of equipment and methods involved in submarine warfare." Although OSRD was exercising its sole authority to write such contracts, NDRC "remained the responsible directing body of the scientific program undertaken."[29]

The shuffling at the top resulted in a reorganization at NDRC, which was divided into twenty-three specialized divisions, one for sub-surface warfare: "This group was number '6,' and throughout the war was simply 'Division 6.' … It would concentrate on what undersea weapons the Navy already had, and it would seek to improve them through small modifications."[30]

The Division 6 headquarters were in New York City near the other divisions of the Office of Scientific Research and Development. Later the group moved to the sixty-fourth floor of the Empire State Building. It was here the Navy ASW

---

[27] *Endless Frontier*, 129.
[28] Library of Congress at http://www.loc.gov/rr/scitech/trs/trsosrd.htmlv visited March 7, 2017.
[29] *Completion Report*, University of California Division of War Research, 30 June 1946, 14-15.
[30] *Hellions of the Deep*, 56-57.

organizations managed by the University of California and Columbia University sent periodic and formal reports on their progress relative to NDRC tasking.

War becomes a reality

While some small number of optimists continued to believe America's safety barriers of two huge oceans would deter even nations as ruthless and well-armed as Germany and Japan, the attack on Pearl Harbor ended that dream. Roosevelt's pledge a year earlier to call up only a small percentage of draft-eligible individuals was brushed aside as thousands of men, young and old, flooded recruiting offices on December 8 and 9 and 10 to enlist. A small percentage of them had previous experience qualifying them for almost immediate service, but most would take months to prepare. The professional military veterans would require those same months to develop tactical operations plans on a scale not seen since the Civil War.

During that period of training and preparation, American and Allied losses continued as the Japanese war machine overran the Philippines, Burma, Singapore, French Indochina, and islands from Wake to Guadalcanal. With the experience of the U-boats in the Atlantic, the U.S. had to concern itself with the possibility of another indefensible submarine threat from the West. Japanese midget submarines, launched from large I-type subs, had been used for reconnaissance and attempted attacks in Hawaii; in fact, the war's first contact, just hours before the waves of aircraft, occurred when USS *Ward* (DD-139) sank a midget submarine attempting to enter the harbor before dawn.[31]

Fortunately, Japanese military doctrine called for submarines to be used for reconnaissance and combat against warships, as opposed to the German doctrine of attacking merchant and convoy shipping, and Pacific submarine battles were relatively few. In the early days of the Pacific War, however, Japan was known to

[31] "Japanese Type A Midget Submarines Used in the Attack on Pearl Harbor," Naval Heritage and History Command, http://www.history.navy.mil/our-collections/photography/wars-and-events/world-war-ii/pearl-harbor-raid/japanese-forces-in-the-pearl-harbor-attack/japanese-midget-submarines-used-in-the-attack-on-pearl-harbor.html, accessed December 16, 2014.

possess long-range submarines (20,000 km or more in range),[32] and Pearl Harbor had shown the vulnerability of American defenses when taken by surprise.

Without certain knowledge of Japanese strategy, the U.S. had to assume its Pacific possessions might be threatened. To the far northeast, the Aleutian Islands of Attu and Kiska were occupied and the main port, Dutch Harbor, shelled. Naval home cities from Seattle to San Diego prepared for bombardment, sabotage, and even invasion. Despite reports of an enemy submarine off the California coast near Long Beach and an actual attack on Ft. Stevens, Oregon, by a Japanese sub in June 1942, the potential threat did not materialize. The two 16-inch guns being installed in Battery Ashburn a few miles south of the Radio and Sound Lab were never fired in anger. There were no wolf-pack attacks on the West Coast.

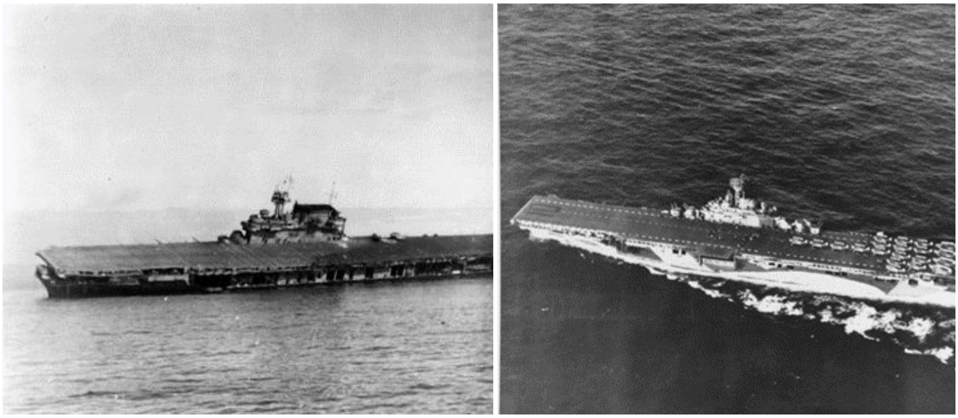
On the other hand, the attack on Pearl Harbor had decimated the Pacific Fleet. The U.S. Navy of December 1941 was a capital ship navy,[33] relying on massive, heavily armor-plated battleships even more heavily armed with nine sixteen-inch guns. Notwithstanding their ability to concentrate enormous firepower on sea and shore, the attack had demonstrated they were vulnerable to the long-range striking capability of attack planes launched from aircraft carriers. With most of those battleships destroyed or heavily damaged, the U.S. Navy's most pressing requirement was to change the quality and the configuration of its fleets quickly.

The June 1942 Battle of Midway, which stopped Japan's eastward thrust, was a clear step in the right direction, since no American "capital" battleships participated. On June 6, four of the six carriers that effected the Pearl Harbor disaster rested on the bottom of the Pacific, with only one American carrier, USS *Yorktown* (CV-5) joining them. The Japanese strategy to occupy Midway and thus take away U.S. landing fields from which American planes could bomb the homeland had failed. And the American Navy built more aircraft carriers.

---

[32] "Submarines of the Imperial Japanese Navy," Combined Fleet, http://www.combinedfleet.com/ss.htm, accessed December 16, 2014.

[33] In their book *America Can Win* (Bethesda, Maryland: Adler & Adler, 1986, 90), Gary S. Hart and William S. Lind declare succinctly: "These characteristics define a capital ship: if the capital ships are beaten, the navy is beaten." Of course, by that definition, the U.S. Navy theoretically was beaten at Pearl Harbor, which suggests a flaw, or at least a shortcoming, in the definition.



USS *Yorktown* (CV-5) (left) was the only U.S. carrier casualty of the Battle of Midway, in which she was seriously damaged by aircraft strikes and finally sunk on June 7, 1942 by a submarine torpedo. She “returned to life” as CV-10, another *Essex*-class carrier named in her honor and commissioned in April 1943, one of more than a score built of the new U.S. “capital ship.”

Unfortunately, June 1942’s confident slogan “Midway to victory” was more a morale booster than a prediction, and despite the victory, uncertainty reigned. With that uncertainty came the requirement to evaluate the cost of such victories. That evaluation resulted in a major component of this story: the assignment of one of those volunteer universities to address weapons shortcomings during that battle, which will be discussed in Chapter 4.

If Midway was not the beginning of the end in the Pacific, it was a remarkable change of naval strategy in a very short amount of time. Japanese aircraft had demonstrated with no room for doubt that aircraft launched from carriers were a formidable force. As those enemy craft had done a few months earlier in Hawaii, so American aircraft had wreaked havoc on enemy ships at Midway. They did so despite an appalling performance of their torpedoes. The designers of those torpedoes had consistently blamed the pilots, but as Captain Sherman Burroughs, who was there, would readily attest, their courage and performance of duty were in reality above reproach.

Naval air takes charge

While the Navy had understood fairly early the potential for a force of operational aircraft in its inventory of platforms, it was slow to develop and integrate that force. As far back as 1921, Army Air Service Colonel William "Billy" Mitchell had demonstrated the power of airplanes on the sea by successfully bombing and sinking three surrendered German ships—a destroyer, the cruiser *Frankfurt*, and the battleship *Ostfriesland*. Mitchell took off from land, but the conclusion was obvious: small planes could defeat huge warships.[34]

The Navy's first attempt at a ship from which planes might operate was USS *Jupiter* (AC-3), an eight-year-old coal carrier whose claims to fame were as the first U.S. Navy turbo-electric-powered ship and the first ship of any kind to transit the Panama Canal from west to east. Renamed USS *Langley* in honor of aeronautical pioneer Samuel Pierpont Langley, the ship pulled into the navy yard at Norfolk, Virginia, where a steel landing strip was bolted onto the hull. Recommissioned March 20, 1922, as the Navy's first aircraft carrier (CV-1), she ushered in the era of U.S. naval aviation.[35]

By 1927, USS *Lexington* (CV-2) and USS *Saratoga* (CV-3), whose original design as battleships was converted in mid-construction to aircraft carriers, introduced the platform/island tower configuration that has distinguished aircraft carriers ever since. And in 1931, the keel of the USS *Ranger* (CV-4) was laid, making it the first Navy ship specifically built as a carrier.

Aircraft design evolved quickly throughout the 1920s and 1930s, as speed, ceiling, endurance, range, and carrying capacity doubled and redoubled in many kinds of aircraft. By the late 1930s, the WWI-era biplane was obsolete everywhere except in air shows, and the Navy had procured more than 5,000 aircraft of all types.[36] Two of the most significant improvements at this time were radio sets,

---

[34] Naval History and Heritage Command, The Naval Bombing Experiments: Bombing Operations. http://www.history.navy.mil/library/online/navybomb2.htm.
[35] "Langley 1 (CV-1)." Naval History and Heritage Command at: https://www.history.navy.mil/research/histories/ship-histories/danfs/l/langley-i.html visited March 20, 2017.
[36] Captain Tim Woldridge, USN (Ret.), *The Golden Age* (U.S. Naval Institute, http://www.usni.org/navalaviation/the-golden-age).

enabling aircraft to communicate with carriers and each other; and more powerful, efficient engines, giving naval aircraft the lifting power to carry heavy weapons like torpedoes and rockets. Unfortunately, as noted earlier, the aircraft were only as good as the weapons they carried, and those weapons were seriously flawed.

At the outset of World War II, the U.S. had seven aircraft carriers (three of them—USS *Enterprise,* USS *Lexington*, and USS *Saratoga*—in the Pacific),[37] but none combat-tested, while Japan had six, all of which had participated effectively in the attack on Pearl Harbor. As noted above, Midway gave an appropriate reason to celebrate and served as a source of pride, but it also demonstrated the Navy's horseshoe nail: if the Navy switched from the battleship to the aircraft carrier as its primary platform, its new capital ship, and the carrier depended on the pilots and aircraft, and their success depended on their weapons, which didn't work, the capital-ship-failure-equals-navy-failure paradigm was once again in play.[38]

Tenth Fleet

As the Pacific Fleet was turning increasingly to aircraft carriers to bolster its decimated surface ship force that would take months to rebuild, the Atlantic Fleet continued its generally unsuccessful effort to stop or at least slow the toll taken on convoys by U-boats. As has been stated, the University of California and Columbia University were tasked in the late spring of 1941 to establish programs dedicated to anti-submarine warfare research and technology development. While these two divisions pursued often basic efforts to solve a vastly complex problem, the fleet continued to do its best with inadequate resources.

Taking some first steps toward coordinating ASW in February 1942, Fleet Admiral Ernest J. King formed a small group within his Commander-in-Chief, U.S. Fleet (COMINCH) staff dedicated to ASW. U-boat attacks continued, however, with horrifying tales of lost lives and crucial war material and common

---

[37] Naval History and Heritage Command, http://www.history.navy.mil/faqs/faq66-9.htm.
[38] Benjamin Franklin: "For want of a nail the shoe was lost/For want of a shoe the horse was lost/For want of a horse the rider was lost/For want of a rider the battle was lost/For want of a battle the kingdom was lost/And all for the want of a horseshoe nail."

necessities sinking to the depths of the sea, and it would take another year before the Navy focused sufficient attention to the problem.

Following a March 1, 1943, meeting in Washington of Allied leaders on the challenge of protecting Atlantic convoys, the U.S., Great Britain, and Canada agreed to a division of responsibility for the effort. The next month, Admiral King began consolidating his staff in order to "launch" a new fleet, one without ships or submarines or aircraft or guns. The U.S. Tenth Fleet, established May 20, 1943, had as its mission the single goal of finding and destroying German U-boats. The COMINCH retained personal command of the fleet, which quickly became the focus for all ASW efforts. He increased the staff and provided them access to all intelligence about U-boats and the authority to direct Navy ships to prosecute them, including specially formed hunter-killer groups. One of those groups, led by the escort carrier USS *Bogue* (CVE-9) with its attached air wing, employed intelligence leads from Tenth Fleet staff to locate and sink *U-569* two days after the formation of the new fleet. It would be the first of many kills for *Bogue*, and the beginning of the end of the U-boat threat.

With substantial sharing of intelligence information among the Allies, a command center at COMINCH headquarters in Washington that became the clearinghouse for all U-boat information, and hunter-killer groups poised to race to the scene of a U-boat detection, the average of four German submarine losses per month jumped to forty-one for the first month of Tenth Fleet's existence.

In July it took only ten hours for Tenth Fleet to intercept radio communications from *U-487* and direct USS *Core* (CVE-13) to its location, and for the carrier to sink it. Of the two U-boats captured during the war, one was the result of Tenth Fleet intelligence. Ultimately, of 1,150 German submarines commissioned during the war, 842 were involved in combat. Of those, 781 were sunk and two were captured.

As will be discussed in Chapter 4, a number of those enemy submarine losses resulted from the weapons developed by one of the two Navy laboratories in California.

Robert S. Gales

Bob Gales was a physics student at UCLA when he joined the Acoustical Society of America in 1940. He had earned his bachelor's degree and worked as a research and teaching assistant while progressing toward his master's degree. With the outbreak of World War II, he moved to San Diego to join the University of California Division of War Research (UCDWR) and contribute to its acoustics research for Navy anti-submarine warfare.

When the war ended, many former UCLA folks returned to the university. Gales was one of a number of UCDWR employees who elected to transfer to the Navy Radio and Sound Laboratory with whom they had collaborated regularly during World War II. His first position was as head of the five-person Psycho-physics Section, part of the early human factors research conducted by what became the U.S. Navy Electronics Laboratory in 1945.

In the early 1960s, Gale was named to head the Listening Division, overseeing underwater acoustics projects. As a result of the 1967 Navy lab reorganization and transfer of functions, he moved (organizationally only; his office remained in place) to the new Naval Undersea Warfare Center. In 1972 he headed the Passive Acoustics Division, the name of which changed two years later to Acoustics, Behavior and Communications Division. Another major organizational change occurred in early 1977 with establishment of the Naval Ocean Systems Center (NOSC), which combined his previous Navy lab with his current one. During the initial several years at NOSC, he headed the Airborne Acoustic Branch, which conducted Project PING, a study of the effect of active sonar pinging on submarine crews, with an eye to improvements in habitability for sailors.

Gales served in several professional and recreational positions: as the Naval Research Associate for the Institute for Naval Studies in 1964, as a member of the National Research Council and on the Armed Forces Committee on Hearing and

Robert S. Gales

Bioacoustics, and commodore of the Mission Bay Yacht Club. After a year as vice president in 1972, he was president-elect, president, and past president of the Acoustical Society of America from 1974 to 1976. He was the second Center scientist so honored (the first was Dr. Robert W. Young in 1960, when he was an NEL employee). At the time of his retirement from federal service, Gales was coordinating, on behalf of the Acoustical Society, a nation-wide network of noise control experts working to make communities quieter. For almost a decade he volunteered as an acoustics expert for the city and later the county of San Diego, serving on noise control boards and assisting in preparation of noise ordinances, thereby saving local governments substantial monies in consulting fees.

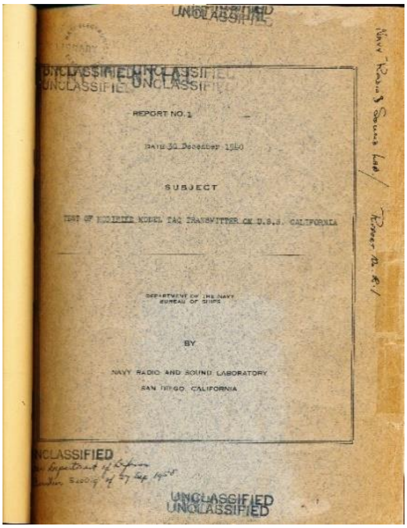
He retired in 1980, but returned for a brief period as a re-employed annuitant and contractor to complete a research project for the Bureau of Land Management "to determine the effects of underwater noise radiated from off-shore oil and gas platforms on marine mammals."[39] The study was in response to Eskimo concern about the effects of drilling on Alaska's North Slope on fish and marine mammal populations.

[39] Naval Ocean Systems Center Outlook, February 13, 1981, 2.

3

The War Years in San Diego

As the summer of 1940 merged into a typical San Diego autumn of warm temperatures and clear skies, Commander J.B. Dow initiated operation of the U.S. Navy Radio and Sound Laboratory, overseeing the small cadre of NRSL personnel as they pursued their assigned duties to evaluate surface ship communication capabilities. (Dow's command tour was decidedly short; by October he had been relieved and was heading for Great Britain to study radio and radar advances before reporting for his next assignment as director of electronics for the Bureau of Ships.) Radio engineer R.B. Owens traveled north to Long Beach to conduct an operational analysis of the power output of the modified radio transmitter on USS *California* (BB-44). The battleship's electronic technology had been upgraded in



UNCLASSIFIED

UNCLASSIFIED UNCLASSIFIED

REPORT NO. 1

DATE 30 December 1940

SUBJECT

TEST OF MODIFIED MODEL TAQ TRANSMITTER ON U.S.S. CALIFORNIA

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS

BY

NAVY RADIO AND SOUND LABORATORY
SAN DIEGO, CALIFORNIA

UNCLASSIFIED

UNCLASSIFIED

An NRSL problem to analyze the modified radio transmitter of USS *California* (BB-44) resulted in the very first of what are now tens of thousands of official reports published by NIWC Pacific and its predecessors. Coincidentally, *California* was the first duty station of Rawson Bennett II, lab commanding officer and director immediately after World War II and later Chief of Naval Research.

several areas, including installation of a CXAM radar, a substantially improved radar set that also went aboard the carrier USS *Yorktown* (CV-5) and four cruisers.[1] Shortly thereafter, *California* and a number of her sister battleships were transferred to Pearl Harbor in the Hawaiian Islands.

Revolution in communications

World War II witnessed the introduction of extraordinary changes in communication technology. From the advanced encryption of messages by Germany's ULTRA machine to the low-tech but effective American Navajo "code talkers," secret messages had never carried such importance among military units. Ship commanders could communicate complex maneuvers among themselves and make quick changes in battle plans. Rugged radios, carried on soldiers' and Marines' backs and in tanks and jeeps, enabled communication during combat with air, land, and sea units. The walkie-talkie handheld radio was introduced just before the war.[2]

As radio and radar developed, increasing numbers of antennas crowded ship masts. Problems multiplied with the complexity of equipment, especially as the press of war caused various technologies to interact without the time to test the effect they might have on each other. It was the responsibility of the Navy Radio and Sound Laboratory to determine the effectiveness of communication antenna operation, and to develop solutions when that effectiveness was impaired.

Over the next five years, Owens and his civilian and military associates would conduct research and testing resulting in forty-six more "R" reports, most of which dealt with antenna studies of ships, and a total of nearly a hundred reports. Reports S-1 through S-25 covered sonar research as well as studies of ship wakes and surveys of harbors (San Pedro, San Francisco, Puget Sound, Pearl Harbor, and Midway Island) for defense installations. There were also twenty-two reports categorized as "WP," detailing radar studies; two (X-1 and X-2) on the subject of radar equipment; and AERO-1: "Note on the Resistance of Electric Hydrometer Elements."

---

[1] Captain Donald Macintyre, Royal Navy (Retired), "Shipborne Radar," U.S. Naval Institute *Proceedings*, September 1967, 73.

[2] "Do You Know this Invention is Canadian?" *The Globe and Mail*, March 20, 2012.

Although his job title defined him as a “radio engineer,” Owens (and the other personnel with whom he worked) was substantially more. In a journal article, the third director of the radio and sound lab, Captain P.H. Hammond, stressed the versatility of his staff:

> If the problem requires that cumbersome pieces of equipment be transferred from the laboratory to a vessel in the harbor, the engineers do it… When in the field, the radio engineer or physicist is often his own truck driver, linesman, rigger, surveyor, and radio operator… he must also be a sailor… a skilled technician…[3]

Writing almost four years after the establishment of the lab, Captain Hammond noted his technical staff numbered only about fifty, and remarked that a variety of challenges (fairly specific experience requirements, space limitations, lack of qualified applicants) resulted in a situation that “expansion in proportion to the potential volume of work that could be assigned to the laboratory is now out of the question.”[4] In discussing his organization, Captain Hammond advised that included himself as the director, an executive officer, and heads of two specific departments, Radio and Sound. He noted these positions were staffed by regular or reserve Navy officers. He also broke down the Radio Department into three divisions—Communications, Radar, and Ultra High Frequency—headed by civilian engineers or physicists, but did not elaborate on the Sound Department.

---

[3] Captain P.H. Hammond, USN (Ret.), “The U.S. Navy Radio and Sound Laboratory,” *Journal of Applied Physics*, Vol. 15, March 1944, 240-242.

[4] *Journal of Applied Physics*, 241. The Congress and President Ulysses S. Grant passed the Civil Service reform law in 1871, creating the first U.S. Civil Service Commission. It was funded for two years, but since Congress relied principally on patronage, funding was not renewed. Grant’s successors, Rutherford B. Hayes and James A. Garfield, were unsuccessful in countering that. Finally, stimulated partially by public outcry at Garfield’s assassination by an angry office-seeker, Congress passed the Pendleton Civil Service Reform Act in 1883, establishing a system in which the best qualified applicants got the jobs. Unfortunately for the NRSL organization, it wasn’t always clear who the best qualified candidates were, since by definition there were no qualified technologists for technologies that did not yet exist. Incompatibility with the bureaucratic uniformity regimens of the Civil Service Commission would continue to challenge the Navy laboratory on Point Loma well into the twenty-first century.

“R” reports

Owens, his associate radio engineer W.F. Squibb, and Navy Chief Radioman D.D. Parkhurst published the second laboratory report in July of 1941. They were authorized by a Bureau of Ships (BuShips) letter assigning to NRSL work on Problem B3-12D, covering measurements of ship antenna installations.[5] The NRSL trio tested transmitting and receiving antennas while the vessels were moored in San Diego Bay.

War-time lab commanding officer and director Captain Philip H. Hammond (left) extolled the versatility of his small staff of radio engineers. He is shown being relieved of command in 1945 by Captain Paul W. Hord.

Report R-4 documents measurements of the antennas on USS *Saratoga* (CV-3), which

> made continuous radio transmissions while turning ship, and the Laboratory measured or recorded the field strength and plotted the observed field strength against the relative bearing of the Laboratory from the ship. The ship was approximately 65 miles west of the Laboratory, and a complete turn was made in approximately 20 minutes.[6]

---

[5] At that time and for a number of years afterward, the tasking assigned to the Navy lab was identified as a “problem,” with an assigned sponsor and number (e.g., BuShips Problem R5-46CD covered radiation by shipboard receiving antennas relating to security hazard, and Problem B22RD dealt with “Ship Type Antenna Systems.”)

[6] No author listed, “Directional Characteristics of Shipboard Transmitting Antennas, U.S.S. SARATOGA, (U),” 8 October 1941 (USNRSL Report R-4).

Published in the fall of 1941, this was the first of numerous lab reports over decades that featured antenna directivity patterns drawn by a polar coordinate printer. Jodi McGee, who would manage the antenna model range division three-quarters of a century later, explained:

> The patterns provide an immediate visualization of the antenna coverage you have and, more importantly, the coverage you don't have. A solid circle demonstrates perfect coverage in every direction. At the points where the trace comes away from the edge of the chart, toward the center, you're losing signal strength in that direction. When the chart shows a dip, that's a null in your antenna pattern in that direction. That lets you know where you've got gaps in your coverage, probably caused by some part of the shipboard superstructure interacting with the antenna.[7]

Antenna measurements of the fairly new *Sims*-class destroyer USS *Hughes* (DD-410) and the late World War I USS *Crosby* (DD-164) were reported in early 1942: "The resulting field intensity was explored from a small boat which circles the ship at approximately two hundred yards... The high frequency receiving antenna... [runs through the ship from the radio room]... thence rises vertically about thirty five feet. The thirty-five-foot rise is well in the clear, almost entirely above the level of the stacks, only partly shielded by the superstructure…"[8]

Studies were also made of three *Albacore*-class submarine antennas in late 1942 and of four other subs the following autumn. A fairly intriguing study was conducted in response to a BuShips request letter of early 1943—potential radio problems resulting from sailors using electric razors aboard ship.[9] Nine different electric razors of four makes were tested in ship compartments and on the deck, with one melodramatic finding: "The visible sparking at the contacts of razor number 4 (the only one thus observed) was quite intense." Sailors on the ship were undoubtedly relieved to read in the report that "it is clear that the operation of electric razors inside compartments of vessels creates no radio hazard to security." Shaving on deck near an antenna, however, was discouraged.

Another report addressing Problem B3-12D summarized a number of observations, tests, and shipboard measurements. The purpose of this study was

[7] Jodi McGee email to Tom LaPuzza, April 28, 2017.

[8] R.T. Brackett, "Radio Hazard to Security of Extremely Small Antenna Voltages—Receiving Antennas of U.S.S. HUGHES and U.S.S. CROSBY, (U)," 14 February 1942 (USNRSL Report R-7), 2.

[9] R.B. Owens, "Electric Razors as a Radio Hazard to Security, (U)," 22 January 1943 (USNRSL Report R-23).

"to obtain the directivity patterns, within the ground wave range, for the vertically polarized component of the radiation."

The engineers described the operation for making antenna measurements:

> In general, the measurement procedure is for the vessel to transmit a continuous signal with locked key, while swinging a tight circle at sea, some miles distance from the laboratory. The signal strength is observed on the laboratory premises, and a continuous chart record is obtained... When possible, the vessel observes the laboratory and sends marking signals at convenient intervals of relative bearing. Otherwise the marks are sent at convenient intervals of true heading, at the same time determining the position of the center of the turning circle from which information the relative bearing of the laboratory can be obtained.[10]

They also mentioned recording antenna patterns from an airplane flying a known course overhead of the ship. Most importantly, they provided recommendations for improving the performance of transmitting antennas, including sizing an antenna to less than a half wavelength at the highest frequency and not erecting an antenna too high over the water to avoid high-angle radiation. The radio engineers, who in a little more than two years had performed in-depth antenna studies of twenty-five to thirty surface ships and aircraft carriers and five submarines,[11] also proposed a solution to a wide-spread fleet problem: communication failures that were historically attributed to enemy jamming or poor weather, although no enemy radiators seemed to be in the area and the weather was clear and sunny. In fact, they reported, those failures were more likely caused by the close positioning of antennas to each other or to a major component of the ship's superstructure. The problem could be solved by relocating a ship's antennas.[12] According to the report, "The antenna should be erected well in the clear, not in the neighborhood of other conducting bodies."[13] That held for receiving as well as transmitting antennas. This research, continued and substantially expanded after the war, would lead to an extraordinary diagnostic apparatus assembled on the heights of Point Loma (see Chapter 5).

A Bureau of Ships letter, dated 15 June 1943, had directed rearrangement of antennas on aircraft carriers, the first of which was completed on USS *Nassau*

---

[10] "Directivity in Shipboard Antennas…," 4.

[11] Numbers based on formal reports published on antennas between December 1940 and early 1943.

[12] Tom LaPuzza, "Information Dominance," *Mains'l Haul, A Journal of Pacific Maritime History,* Vol. 48; 3&4, Summer/Fall 2012, 26. Also, NOSC, *Fifty Years of Research and Development on Point Loma*, 11.

[13] "Directivity in Shipboard Antennas…," 9.

(CVE-16) by Mare Island Navy Yard. Since *Nassau* was the first carrier so modified to arrive in San Diego, “Laboratory engineers inspected the antenna installation carefully and made every effort to obtain as much information as possible during the limited availability of the vessel.”[14] With the ship a dozen miles at sea, radiation patterns of the transmitting antennas were recorded while the vessel turned in tight circles. Their conclusion, “In general, the new transmitting antenna system of the U.S.S. NASSAU appears to be relatively satisfactory. In addition, the directivity characteristics of most of the antennas seem superior to those previously observed on vessels of this class.”[15]

“S” reports

While the “R” reports provided detail on NRSL’s primary responsibility related to shipboard antennas, the “S” series of reports related efforts on sonar research, ship wake studies, and harbor defense work. Waldo Lyon, two other physicists, and a radio engineer addressed BuShips Problem U2-8D in a study of “sono-impulse recorders.”[16] These recorders were employed in training destroyer personnel to determine the effectiveness of depth charge patterns for anti-submarine warfare. Fitting the “target” sub with microphones “bow, amidships and stern,” the researchers employed two instruments, one “designed to determine the relative bearings and ranges of practice bombs,” and the second “to locate practice depth bombs anywhere with[in] a range of 200 feet at variable depths.”

The submarine S-35 was employed for the tests, cruising at periscope depth at speeds up to seven knots. Dynamite caps were exploded for the sound source. At higher speeds, a practice bomb was developed and “loaded to fall at a speed equal to that of a 300 lb [sic] depth charge.”[17]

---

[14] S.R. Radom, “Directivity Characteristics of the New Antennas on the U.S.S. NASSAU –CVE 16,” 25 November 1943, (NRSL Report R-36), 2.
[15] “Directivity…CVE 16,” 13.
[16] W.K. Lyon, “Development of SONO-Impulse Recorders,” 20 February 1942 (NRSL Report S-1).
[17] “SONO-Impulse Recorders,” 4.

Another early S-report detailed studies of ship wakes, explaining,

> From a practical point of view an understanding of the acoustic behavior of wakes is highly important not only because of the difficulties encountered in echo ranging when wakes are present but also because of the possibilities of utilizing wakes for concealment or detection in submarine and antisubmarine warfare. By employing the Navy NK-1 shallow depth recorder a useful technique for the study of wakes has been developed. Observations in the laboratory pool and on surface ship wakes have already yielded pertinent data...[18]

The "laboratory pool" was described as thirty-one feet in length, eleven feet wide, and seven feet deep, filled with fresh water. No additional information was provided. (UCDWR personnel also used the pool for their research, and in one report described it as being constructed of concrete, but again with no additional information.)

Subsequent contact with Dr. John Hood, an optics expert working at the Navy Electronics Laboratory/Naval Electronics Laboratory Center from the mid-1950s to the mid-1970s, provided details on the pool, located in the Navy lab's first building on Point Loma:

> Bldg. 4 was O shaped. [Follow-up email the next day clarified: "The building was square, of course. What I meant was the offices and lab completely encircled the pool area. Call it a square O."] The pool was on the same level as all the spaces, right in the middle, open to the sky above. There was a concrete wall around it about two or three feet high and a concrete walkway right around the whole thing, probably four or five feet wide… We had the pool demolished—quite a spectacle—we all took time off to watch the workers break down the walls and fill the pool with the wall debris… I have no idea what's in there now but when I was there it was a windowless lab producing the first liquid laser in the world.[19]

The ship wake report detailed study of the mechanism of sound reflection demonstrated in acoustic wake behavior, which was defined as "any region of water which by virtue of its motion or contents has and maintains the property of reflecting sound over an extended period of time."[20] This was significant due to the substantial differences between the visible foam and turbulent water wake of a ship underway and its acoustic wake. The former spreads widely in a direction perpendicular to the ship's course, while the latter is no wider than the ship itself. More importantly, the latter persisted (and thus was evidence of the passage of the

---

[18] Norman J. Holter and Lieutenant Roger Revelle, USNR, "Investigation of Surface Ship Wakes," 1 December 1942 (NRSL Report S-3), 2.
[19] Dr. John Hood email to Tom LaPuzza, August 9, 2017.
[20] John Hood email, August 9, 2017.

ship) long after the visible wake disappeared, in one experimental instance, cited in Hood's email, for twenty-one minutes.

The first report detailing a harbor defense study is S-4.[21] Navy reserve lieutenants Chesney R. Moe and Jess O. Long spent three weeks in San Francisco at the end of 1942, directing work of "officers, enlisted personnel, and engineers attached to the U.S. Navy Radio and Sound Laboratory, assisted by members of the Staff of the University of California, Division of War Research" (including Waldo Lyon and Lt. Roger Revelle of the lab and Eugene LaFond of UCDWR). Their purpose was "to determine the feasibility of planting eight Model JM-1 sono-buoys in an area included in a circle of about six miles radius centered on the Golden Gate Bridge." Employing Coast and Geodetic Survey charts, the team conducted extensive bottom surveys from the bridge to about five miles out, including topography/water depth, salinity, tidal action, currents, and sound reflection as affected by the various bottom compositions of sand, gravel, and rock.

Returning to San Diego, the team put together a report with recommendations on appropriate locations and type of equipment to be positioned at those locations, to provide warning of enemy submarines attempting to enter San Francisco Bay. One device discussed was a HERALD, sometimes rendered as Herald, defined elsewhere as a "coined term" for Harbor Echo-Ranging And Listening Device.[22]

In a similar (and the next) report, Lt. Moe directed some of the same NRSL and UCDWR personnel to consider HERALD locations in the Seattle area. Lt. Moe reported,

> The purpose of Herald installations is primarily to detect enemy surface vessels and submerged enemy submarines attempting to enter the protected area.... [particularly useful when a sub is trying to disguise itself in the screening action of a surface vessel's wake]... Herald equipment will be able to supplement echo-ranging and listening equipment of patrol vessels.[23]

The studies by the two lieutenants were directed at preventing enemy subs from entering U.S. harbors, particularly on the West Coast. With minor exceptions, the threat was more anticipated than real.

---

[21] C.R. Moe, "Survey of San Francisco Harbor to Determine the Suitability of Proposed Locations for Harbor Defense Installations." 23 January 1943 (NRSL Report S-4).
[22] U.S. Patent 2,524,847 of Oct. 10, 1950, "Herald Trainer," inventor Earl W. Springer.
[23] C.R. Moe, "Survey of Puget Sound Area – Report on the Suitability of Possible Herald Locations, Strait…Inlet," 1 February 1943 (NRSL Report S-5), 3.

In the Atlantic, on the other hand, for the months preceding and initiating World War II, the German wolf packs were in command. Fortunately, to some degree, their mission was to prevent re-supply convoys from reaching England. If their purpose had been to wreak havoc in New York and Boston and thus spread fear and panic across the country, they might have been successful:

> The citizens would have felt even worse had they known how really unprepared the country was. For example, here is a typical urgent dispatch sent to Commander in Chief of the Fleet Admiral Ernest J. King, from Vice Admiral Adolphus Andrews, commander of the North Atlantic Naval Coastal Frontier, in late December 1941: 'Should enemy submarines operate off [the East Coast], this command has no force available to take adequate actions against them either offensively or defensively.'[24]

Robert Gannon, who wrote a detailed text on American development of torpedoes during the war, suggests how close the danger really was:

> And in truth, U-boats were already cruising the coast. Germany by this time had some 200 ocean-class submarines and was producing another 20 a month. Both the U-boat types IXC and IXB could make the 22-day, 3,000-mile Atlantic trip to the United States coast and have enough fuel left for a week or two of maneuvering and return. While there, the German subs could choose among the fifty daily ship arrivals and departures from New York City alone.[25]

In point of fact, the Germans not only operated there, but in several cases blockaded harbors along the Atlantic seaboard with mine-laying submarines—New York for several days in late 1942 and Chesapeake Bay for a total of five days in June and September.[26]

It was to support addressing this threat that the University of California laboratory was established at NRSL.

Underwater acoustics

While the NRSL civilian and military radio engineers and technicians made straightforward signal strength measurements of shipboard antennas, their coworker physicists and University of California associates with whom they

[24] Lagislas Farago, *The Tenth Fleet* (New York: Ivan Oboloensky, 1962), 51. Quoted in Robert Gannon, *Hellions of the Deep*.
[25] *Hellions of the Deep*, 10.
[26] James Phinney Baxter III, *Scientists Against Time* (Cambridge, Mass.: The MIT Press, 1946), 39.

worked frequently were struggling to understand the complexities of sound traveling underwater. It was a scientific discipline little studied prior to World War II, but one of the key areas of interest to both NRSL and the ASW labs established by the National Defense Research Committee (NDRC).

According to the Navy laboratory's fiftieth anniversary publication,

> The maximum effort and greatest contributions of both NRSL and UCDWR between 1941 and 1943 were in research. The physics of sound in the sea was not well understood. Sound propagation can be greatly affected by currents, marine organisms, water temperature, salinity, depth, and the structure of the ocean bottom.[27]

As a result, NRSL and UCDWR, separately and in joint projects, studied sound propagation, sound scattering, target strength, ambient noise, and related topics. A large number of the Navy lab's hundred reports during the war, and a majority of the thousand reports generated by the UC researchers, deal with those subjects. Like the Columbia University Division of War Research on the East Coast, the West Coast physicists, acousticians, and marine biologists used their scientific knowledge and ingenuity to pursue an array of approaches designed with a dual-purpose goal in mind: keep the undersea environment as safe as possible for U.S. submarines and make it as dangerous as possible for enemy boats.

Echo-sounding systems called fathometers had been developed in the 1920s for the purpose of mapping coastal waters; they measured the major canyons and seamounts on the continental shelf and were essential in coastal mapping (attenuation and other factors made them less effective at deep-water surveys).[28] Teams at the Point Loma enclave used fathometers to calibrate environmental factors, such as the contour of the sea bottom or (looking up from a submarine's perspective) the distinct sounds and speed of ship wakes, which helped identify the size, location, and direction of unfriendly surface ships.

The harbor-defense efforts particularly made use of underwater acoustics to design an environment dangerous to an intruding enemy submarine. Various sensors, HERALD equipment, "curtains" of bubbles, and, when all else failed,

---

[27] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*, NOSC Technical Document 1940, 1990, 12.

[28] "History of NOAA Ocean Exploration/Age of Electronics (1923–1945)," National Oceanic and Atmospheric Administration, accessed December 20, 2014, http://oceanexplorer.noaa.gov/history/electronic/electronic.html.

Scientists from the Point Loma Navy lab and UCDWR worked cooperatively to understand the emerging technology of underwater acoustics, critical to locating enemy submarines and protecting U.S. subs.

underwater nets were placed at strategic points on harbor bottoms to ensure such an intruder was sensed immediately so counter-attack could begin.

Waldo Lyon was one of those involved in the harbor-defense efforts in both San Francisco and Puget Sound. He related what was a reverse benefit to the studies: by studying the acoustic properties of harbors and setting up equipment to detect enemy submarines, the teams also gained insight into how their own subs might use those properties to evade detection devices:

> The Pacific was really pro-submarine warfare, much more than anti-submarine warfare, so… about two and a half or three years of it was on how to get through harbor-defense systems... of all types, and then what submarines could do using the currents, temperature profiles and what not in a particular place to avoid being detected getting into harbors.[29]

"Pro-submarine" is a seldom-heard term meaning the technologies that

[29] *The Reminiscences of Dr. Waldo K. Lyon*. Interviews conducted by Commander Etta.

promote the offensive mission of a submarine, and these include both the ability to find a target and destroy it and to evade detection or destruction. Much more than the Radio and Sound Lab personnel, the University of California scientists concentrated on pro-submarine warfare, inventing methods to avoid detection, studying the endless complexities of sound and radio waves in the ocean.

The various trips to the Strait of Juan de Fuca were intended to provide the Navy knowledge on behavior of its instruments in irregular, shallow straits, such as those surrounding the Japanese home islands, where submarines would face robust harbor defense systems—forests of undersea mines, listening devices, and ships with depth charges. For Waldo Lyon, those trips be life-changing.

While working on the harbor-defense studies, he grew intrigued with the behavior of sound in cold water. For him, that area of study appeared so difficult and tantalizing he would make it his life's work after the war. His interest was shared by Canadian scientists working in Nanaimo, British Columbia. The Canadians focused on their country's heavy responsibilities in the Atlantic, and their Pacific involvement was mostly limited to coastal defense, but Lyon commented the very lack of resources forced his allies to "better thinking than we did just because they had less."[30] His connections to the oceanographic group in Nanaimo would become important a decade later when addressing the seemingly impossible task of learning to navigate under arctic ice.

Radar studies

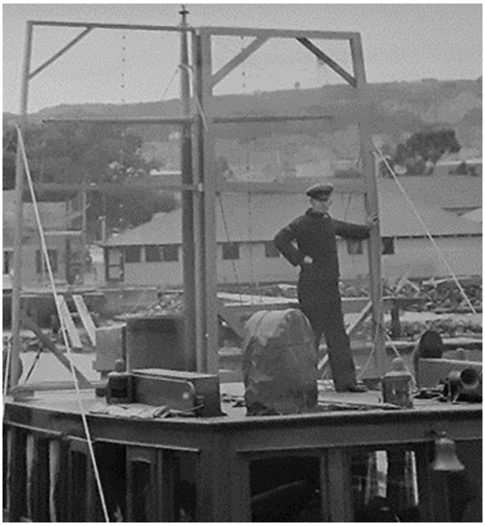
In addition to the work on antennas and pro- and anti-submarine warfare, Navy Radio and Sound Lab personnel also conducted substantial studies of radar, work that continues at NIWC Pacific today. During World War II, between the fall of 1942 and September 1945, more than twenty formal reports were published, detailing studies of radar propagation, calibration of radar equipment, and use of "wired sondes" (captive balloons) to sound the atmosphere for temperature and humidity data. The first of the radar reports briefly describes an "investigation of possibility of aircraft using Radar blind zones to come in undetected."[31]

[30] *Reminiscences*, 7-8.
[31] R.V. Keeran, Jr., E.F. Kiernan, A.F. Deming, H.E. Reppert, "Report of Equipment used in experiments on Radar Blind Zones for Approach," 14 October 1942, NRSL WP-1, 1.

Another of the earliest reports deals reasonably with the basics:

> The investigation described herein was undertaken to determine certain of the basic laws governing so-called Radar echoes from metallic surfaces over the ocean. Factors considered are the law of attenuation with distance in free space and over sea water, the reflection coefficient of the sea surface and the spatial radiation pattern resulting from interference between the direct ray and the rays reflected by the sea surface.[32]

In a somewhat lengthy text and twenty-eight illustrative "plates" (photos and graphs), the authors describe their procedures for and results of experiments on radar attenuation with distance, particularly over the ocean. They provide a large number of equations developed to compute the parameters characterizing radar performance.



An early study of radar wave propagation employed an antenna on top of Point Loma and a plane reflector of galvanized iron mesh screen mounted on a small craft offshore from the lab's waterfront.

[32] Lloyd Anderson, John B. Smith, F.R. Abbott, Lt. Roger Revelle, USNR, "Radar Wave Propagation," 30 November 1942 (NRSL Report WP-2), 3.

WP-5, "Report on Radar Wave Propagation: Atmospheric Refraction—A Qualitative Investigation,"[33] cites two previous radar reports and concludes, "... the maximum range at various altitudes can be predicted when weather forecasts are available." Providing an example of a frequent local atmospheric condition (Point Loma socked in by fog), the authors explain that an aircraft flying in this layer of fog at 5,000 feet can be detected at a range of eight miles, while one flying much lower (300 feet) will show up on the radar screen at a distance of thirty-five miles. "The military value of such knowledge is obvious."

In one instance, the study of radar measurements related to weather had to be pursued at some distance from the lab: studying "K-Band Attenuation due to Rainfall"[34] proved much more difficult in San Diego, with an annual rainfall of 10.1 inches, than in the vicinity of Hilo, Hawaii, which receives in excess of 250 inches of rain a year. The report includes an interesting discussion on use of

> ordinary office blotters of 38 sq. inches area [which] were lightly dusted with powdered potassium permanganate and exposed to the rain for a long enough time to collect 100 to 300 drops. Upon contact with the blotter, each drop dissolved a small amount of permanganate and made a purple spot whose diameter was a function of the volume of the drop.

The researchers established a 1.21-statute-mile link near Hilo to determine the effect of those raindrops on K-band (1.25 cm. wave length) radiation, and, using ninety-five blotters, determined, "The average attenuation of 1.25 cm radiation due to rainfall is 0.37 db/mile/mm/hr... The exact effect of drop size upon attenuation is still experimentally undetermined."[35] In another application, a radar beacon was designed to be dropped from a pilot plane to "guide following flights to difficult targets."[36]

Perhaps the lab's most significant contribution to the war effort in this area was the training of radar operators, although it represented a fairly challenging assignment. As will be discussed below, UCDWR personnel provided extensive training to sonar operators. While the university's division was specifically tasked

---

[33] Lloyd Anderson…7 May 1943, 1.
[34] L.J. Anderson and five associates, WP-20, 8 June 1945.
[35] WP-20, 5.
[36] Captain P.H. Hammond, U.S. Navy Radio and Sound Laboratory Quarterly Report, September 1945, 11.

with training as one of its responsibilities,[37] the Radio and Sound Lab had neither the facilities nor the personnel for this task.

In drawing attention to this fact, NRSL's second director, Captain W.J. Ruble, notified the chief of the Bureau of Naval Personnel in a detailed memorandum that "instruction of Fleet Fire Control students in Radar operation has been underway at this Laboratory since July 1941."[38] He advised continuous classes of twelve Coast Guard personnel "reported on the first and fifteenth of each month... for instruction in Radar operation." Additionally, he said, significant numbers of personnel from Fleet Fire Control School, Naval Air Station San Diego, and other Navy and Marine commands had attended or were scheduled to attend classes.

To achieve that, "it has been necessary to divert professional scientists and engineers from other problems and work assigned by the Bureau of Ships and utilize their services as Radar instructors," which "materially retarded" that work. He requested one officer and ten enlisted personnel for support and recommended establishment of a radar school on property recently turned over to NRSL. With endorsement from the Commandant of the Eleventh Naval District,[39] who recommended the radar instruction be under the cognizance of the NRSL director, the Chief of Naval Personnel authorized establishment of the school on Point Loma, specifying course size, duration, and curriculum.[40]

In the middle of that chain of letters, the top fleet official, Commander-in-Chief, U.S. Fleet, mandated there be no civilian personnel on the training staff. Unfortunately, Captain Ruble had few military personnel available and so was using mainly NRSL civilians to perform the training. The order thus presented a substantial setback for the effort, although in an equally substantial positive manner it would free up radio and sound lab technical personnel to return to their assigned tasks. After consulting with Captain Ruble, COMINCH understood the situation, advising "it now seems more desirable to reverse the above opinion." [41]

---

[37] University of California Division of War Research, *Completion Report*, June 30, 1946, 24.

[38] U.S. Navy Radio and Sound Laboratory letter Serial C-RS-328 dated 10 June 1942, 1.

[39] ND11/S67, Serial C767 dated June 20, 1942.

[40] Pers-1443-LMO of August 20, 1942.

[41] Letter from Commander-in-Chief, U.S. Fleet to Chief of Naval Personnel, COMINCH Conf ltr FF1/S67-1/P11-1 Serial 1479, dated July 23, 1942.

Captain Ruble did make one last attempt to explain the attendant consequences of assigning the school to, and locating it at, his organization:

> At the present time the commissioned, enlisted and civilian personnel employed full or part time in the instruction of Radar personnel are almost entirely composed of members of the scientific staff of the Laboratory. Under present conditions there is no satisfactory manner in which this [sic] personnel and its activities can be separated from Laboratory activities and designated as a 'Radar Operator's School.' It is therefore recommended that the designation 'Radar Operator's School' be deferred until the activities can be established elsewhere with a separate identity.[42]

Subsequent letters, with some small amount of bureaucratic nit-picking, sought and gained approval for funding in the amount of $85,000 to construct and furnish an actual building for the school.

While the training effort ceased prior to the end of WWII, the radar development at the Point Loma laboratory continues to the present. One of the earliest efforts in that area earned high-level praise half a century later. A letter of congratulations sent to the laboratory on its fiftieth anniversary in 1990 notes that NRSL tested the Navy's first operational radar set.[43] Built by RCA and first tested on the battleship USS *Texas* (BB-35) in 1939, the ungainly T-shaped set was brought to the laboratory in 1940 and positioned on the restricted laboratory "penthouse" roof, recalled its operator, radio engineer H. E. Reppert. From there, it correctly spotted American destroyers concealed by darkness three and a half miles off Point Loma.[44]

Director's biweekly reports

While his scientists and engineers wrote and published formal reports on their research, the third NRSL director and commanding officer, Captain P.H. Hammond, initiated a series of what eventually would be fifty-five biweekly reports to his immediate senior in charge, the chief of the Navy's Bureau of Ships. In the first one dated March 10, 1943, he reported on work in the laboratory's

---

[42] NRSL Director letter to Chief of the Bureau of Personnel, ND11/NP22/NC, Serial C-RS-423, dated 1 September 1942.

[43] Gerald A. Cann, Assistant Secretary of the Navy. Official letter dated May 25, 1990. Reproduced in *Fifty Years of Research and Development on Point Loma*, C-2.

[44] "Navy's Pioneer Radar Protected San Diego Area," The San Diego *Union*, October 1, 1946.

Sound Division, citing "the present status and the progress made on particular projects underway."[45] Captain Hammond included ten general and specific topics he would repeat in many of his later reports:

- Harbor Surveys
- Study of Wakes
- Tide Current Meters
- Optical Sound Bearing System
- Acoustic Torpedo Detector
- Submarine Charging Batteries
- Shipborne Attack Teacher
- Roll-Pitch Corrector for Tilt Beam Projector, Attack-Plans Position Plotter
- Sono-Impulse Recorder
- Fleet Service

Subsequent reports discussed a number of other topics/projects, some repeated rather frequently, e.g., the Sono-Optical Recorder, gate protection, and the Depth Charge Direction Indicator. Like the comparable UCDWR reports to be discussed shortly, these reports provide a summary narrative of the significant and varied technical work pursued by NRSL during most of the war's duration. Detailed descriptions of the most significant project work were published, as projects were completed, in the formal reports discussed above.

While the majority of the work pursued by NRSL engineers resulted from BuShips tasking, the lab also responded to short-term requirements out in the harbor. In his *Journal of Applied Physics* article,[46] Captain Hammond listed ten components of the NRSL mission, the very first of which was "to provide expert technical assistance to fleet or unit commanders." Based on that, fleet support appeared to be his first priority. His biweekly reports include numerous citations of assistance provided to ships in the harbor: "Inspected WEA-1 equipment on U.S.S. SC572 at the request of the Commanding Officer"; "At the request of the Commanding Officer, assistance was given the U.S.S. YP-37 in the solution of keying troubles in their QBE equipment"; "At the request of the Communications

---

[45] The title "Radio and Sound Lab," and the fact the fifty-five reports are all on Sound Division projects, suggest a similar biweekly report of the Radio Division. That seems particularly appropriate since the BuShips sponsor to whom the reports were sent, Captain J.B. Dow (coincidentally the first NRSL Director), was a Navy radio engineer and, one assumes, most interested in findings related to radios. Extensive research in NIWC Pacific library holdings and similar efforts with the Naval History and Heritage Command and the U.S. National Archives have failed so far to find such reports.

[46] "The U.S. Navy Radio and Sound Laboratory," 240-242.

Officer of the U.S.S. DE-29, an inspection was made to determine the nature and cause of the difficulty reported in using the ship's public address system."[47]

One "Fleet Service" project cited in several reports in April 1944 was modification of the commercial fathometer on USS *Midway* (CV-41) in attempts to hear propeller noise of nearby ships and also in "transmitting signals on the fathometer to a listening vessel, in particular a submarine, when in deep water."[48]

In concluding his journal article, Captain Hammond proudly stated,

> Off the record, but a source of considerable gratification to the laboratory engineers, is their service to vessels of the fleet that may be in the area for a limited time. During routine visits to vessels they are often asked for assistance in solving some problem of a critical nature. Regardless of the nature of the problem and the time limitations, they have yet to record an instance of having had to see the vessel leave with its problem unsolved.[49]

In a preview of what would be one of the organization's significant capabilities two decades later, Captain Hammond reported the lab, at the request of Naval Air Station North Island, had been assisting in locating objects lost at sea outside the harbor. Several objects had been found, "but efforts to retrieve any of them have been unsuccessful."[50] After delays in the project due to lack of an appropriate vessel, he was able to report: "... assistance was given to the District Mine Disposal Officer in the location and recovery of a test torpedo lost in 125 feet of water."[51] A month later he reported further assistance to the mine officer in the search for a lost test torpedo at Morris Dam. (Interestingly, organizational mergers would put the Morris Dam facility under the Point Loma Navy lab in time.)

The weapon recovery efforts foreshadow the capabilities developed many years later in the Cable-controlled Underwater Recovery Vehicle (see Chapter 13) and the Mark 5 Marine Mammal System (see Chapter 8).

Captain Hammond continued his biweekly reports until celebration of V-E (Victory in Europe) Day on May 8-9. He published and circulated his last, the fifty-fifth, dated 23 June 1945, covering the period 13 May through 9 June. For historical purposes, perhaps, he began the report, which at seven pages was his

---

[47] P.H. Hammond, U.S. Navy Radio and Sound Laboratory Sound Division, Biweekly Report No. 1 as of March 6, 1943, 3; No. 10 as of July 16, 1943, 3; and No. 17 as of 16 October 1943, 2, respectively.
[48] Biweekly Report No. 31 as of 26 April 1944, 2.
[49] "The U.S. Navy Radio and Sound Laboratory," 242.
[50] Biweekly Report No. 1 as of 18 September 1943, 2.
[51] Biweekly Report No.17 as of 16 October 1943, 2.

longest, with a notification the Bureau of Ships sought alternate reporting relative to specific projects ("problems"). He also noted there was no longer a need for a widely circulated report of this type.

University of California Division of War Research

Webster's defines history as "a systematic written account of events, particularly of those affecting a nation, institution, science, or art, and usually connected with a philosophical explanation of their causes."[52]

With a significant amount of research, numerous interviews (although the people involved are probably all deceased), and collection of archival documents, one might construct a history of the University of California Division of War Research. Such a history would be from a perspective decades later and would almost certainly be colored by events that had not yet occurred when UCDWR was in operation, but it might have some merit. On the other hand, thanks to the U.S. Navy's World War II-era Bureau of Ships, the interested student of such a history merely has to read *Completion Report, made to the Chief of the Bureau of Ships, Navy Department covering operations of the University of California Division of War Research at the U.S. Navy Electronics Laboratory, San Diego, California under Contract NObs-2074 (formerly OEMsr-30), June 30, 1946.*[53]

As discussed in Chapter 1, the National Defense Research Committee created ASW organizations on each coast in April 1941 to address the German U-boat menace. The Office of Scientific Research and Development, which awarded contract OEMsr-30 to the University of California to establish its war-time division, turned that contract over to the Navy's Bureau of Ships on March 1, 1945.

BuShips, under a nearly identical contract re-named NObs-2074 (one minor change extended the contract to 30 June 1946), required the university to develop "a complete final report of its findings and conclusions in connection with services

[52] *Webster's International Dictionary of the English Language*, Second Edition, Unabridged (Springfield, Mass.: G7C, Merriam Company, Publishers, 1959), 1183.

[53] Although UCDWR had worked with (and "at") the U.S. Navy Radio and Sound Laboratory throughout the war, NRSL's title was changed to U.S. Navy Electronics Laboratory in late November 1945 as the *Completion Report* was being written. The extended title suggests UCDWR's operations were conducted at NEL, when in fact, except for the close-out of its studies, all of its work was done at NRSL.

under this Contract." UC complied, with a 318-page report illustrated with the cartoons and graphics characteristic of the time and with all the detail required to satisfy the most devoted student of history.

The Navy bureau had this remarkably wise concept in mind in stating the requirement:

> The problems in organizing a large and active research laboratory are many and various; a thorough discussion of these problems and the ways in which they were solved, would be useful for reference in case necessity required the organization of a similar laboratory.[54]

Or in case someone wanted to write a history of that laboratory.

Using the invaluable resource of the completion report, written during the final months of the division's operation as the Navy Radio and Sound Lab was taking over most of its projects and many of its people, we will attempt to present a history of UCDWR that is compelling but substantially shorter. We will augment it with the two other valuable resources the division generated as it was winding down its operation: the list of all its employees, collected in a booklet[55] that includes job titles and photos for most (and, in those pre-Personally Identifiable Information days, their home addresses); and its own bibliography, the listing of the nearly one thousand reports generated by the division.[56]

As the Navy Radio and Sound Lab director produced reports to his superior at the Bureau of Ships, UCDWR fulfilled its contractual obligation by sending similar reports to the Office of Scientific Research and Development, National Defense Research Committee, from June 29, 1942 through February 3, 1945. Those also will be used in reporting on the division's WWII accomplishments.

UCDWR staff

The University of California Division of War Research (initially the University of California Division of National Defense Research) employed almost

---

[54] *Completion Report*, 5.

[55] University of California Division of War Research Roster 1941-1945.

[56] *Completion Report*, Pages 245-318 list the reports categorized by subject, e.g., sonar performance studies, acoustic properties of wakes, transmission of underwater sound. The largest category, with fifty-four reports, covered one of the division's most important products—the QLA FM sonar

1,100 persons between 1940 and 1945, essentially the period of its contract with the NDRC/OSRD. At full capacity, nearly 600 were on its personnel roll, most of them scientists and engineers, but large numbers of them working as buyers, chauffeurs, draftsmen, editors, illustrators, librarians, metal smiths, photographers, telephone operators, secretaries, stenographers, and other administrative and trade jobs. A fairly large number were women, who worked in all of those roles listed. The majority of their job titles included "clerk" or "technical clerk," and these were the computers, calculators, and other jobs requiring significant mathematical, technical, and scientific knowledge.[57]

One example was Barbara Root, who joined the UC staff July 3, 1942, as "Assistant Computer." Four years earlier, noted her hometown newspaper, the teenage Root had been elected "Queen of the High Jinx" at Corona Union High School. But high jinx were suspended for the duration of the war, and UCDWR needed people with a talent for mathematics. Despite the secondary professional status of women generally in American society, Root and many other women found their professional beginnings in scientific war work.[58]

The formal scientific jobs were held by men with advanced degrees, as one might expect of a technical organization of that time. The roster of wartime employees reveals most men working for the university during the war were not academics but worked in supporting roles: engineers, machinists, welders, construction engineers, and crews of boats for sea tests. Like the women's "clerk," the men's catch-all title was "engineer," covering a range of skills.

The division's mission was to invent technologies that did not yet exist, and to improve young and primitive ones like radar and sonar. This posed a puzzle for its leadership: If a technology does not exist, whom do you hire to develop it?[59] These were early days in electronics, and so employees were brought on who showed promise, or whose skills seemed adaptable to the task. The division's first director, Dr. Vern Knudsen, even recruited some staffers from Hollywood, which had produced "talking pictures" for thirteen years by 1940. Skill with recording equipment, he knew, would be needed for testing sound devices, for research, and for innovating in underwater acoustics. Arthur Roshon had joined the Walt Disney studio in 1943; he would make significant contributions in engineering the

---

[57] UCDWR Laboratory Roster 1941–1945. Also, various entries in the bi-weekly reports.
[58] University of California Division of National Defense Research Bi-Weekly Report Covering Period June 29–July 11, 1942, 3. Also, Corona *Courier*, April 15, 1938, 1.
[59] "This issue exists and has been debated in the 21st century!" Carmela Keeney, SSC Pacific Executive Director, 2005-2017, in manuscript review note.

breakthrough QLA sonar, and would become the partner of NRSL's Dr. Waldo Lyon as they labored to make submarines capable of navigating under ice.[60]

It was a learn-by-doing group. By the end of the war, Director Gaylord P. Harnwell would write,

> There have been… technically trained personnel, as well as people with little or no previous technical training. In some instances, housewives and high school students joined to help us in our phase of the war effort. In but a few cases have any of us had past experience that fitted us for the particular technical work upon which we have been engaged…. [61]

(As will be noted in several instances in this history, the requirement of the Navy labs to invent not only specific hardware but also entirely new technologies required substantial creativity on the part of the individuals involved.)

The division functioned rather like a modern product research and development laboratory, requiring administration and infrastructure like any corporation. As a contractor of the federal government, it was essential that strict accounting practices be employed to ensure funding was received, put to appropriate use, and reported back to government auditors.

The university's original intent was to operate business functions at its campus in Los Angeles, but that proved unworkable. In the pre-computer age, the hundred-plus-mile distance was too great. In response to that challenge, the university assigned a member of its business staff as laboratory business manager, located in one of the two major UCDWR buildings on Point Loma. With his arrival, administrative functions like personnel and purchasing were soon centralized.[62]

Leadership of the division

Dr. Gaylord P. Harnwell succeeded Dr. Vern O. Knudsen as director of UCDWR in April 1942 (the organizational title had been changed in the fall of 1941) and remained its civilian leader until the end of the war. With a doctorate from Princeton in 1927, Harnwell was a research leader at California Institute of

---

[60] *Fifty Years of Research and Development on Point Loma*, 8. Also, Waldo K. Lyon, "The submarine [sic] and the Arctic Ocean," *New Scientist*, No. 343, 13 June 1963, 587 591.
[61] Dr. Gaylord P. Harnwell, "Introduction." University of California Division of War Research at the U.S. Navy Radio and Sound Laboratory Roster 1941–1945, 2.
[62] *Completion Report*, 180.

Technology and chairman of the Department of Physics at the University of Pennsylvania.[63] An able administrator as well as distinguished physicist, Harnwell would earn the Medal of Merit from the Navy for his contributions to sonar during the war. Even while managing the laboratory, Harnwell remained editor of *The Review of Scientific Instruments of the American Institute of Physics*, a leading technical journal. After a period of executive personnel instability immediately following Knudsen's departure, Harnwell was supported by three assistant directors, each a distinguished scientist/ professor of either physics or engineering:

Dr. Gaylord P. Harnwell

Dr. H.E. Hartwig of the University of Minnesota headed the training division; Dr. Carl Eckart of the University of Chicago was responsible for "fundamental research," which later became the Sonar Data Division; and Dr. F.N.D. Kurie, an Indiana University scientist, headed the Sonar Devices Division. (Eckart would relieve Harnwell during the close-out period of UCDWR and become the founding director of the Scripps Marine Physical Laboratory. Kurie would return to academia for some years, but would later return to Point Loma as the first technical director of the Navy Electronics Laboratory.)

63 "Gaylord Probasco Harnwell (1903–1982)" Penn Biographies, University Archives & Records Center, University of Pennsylvania.

Wartime technical work

An early problem addressed by the UC division was to correlate the sounds of propeller screws with the thermal distribution of the sounds, so ships and submarines might more accurately know an enemy ship's range. In the summer of 1942, the UC researchers tested the sound of screws from destroyers, tugs, tankers, and fishing boats, and observed that the maximum listening ranges exceeded the calculated listening ranges by a factor of two to eight. The experiments continued through that fall to record listening data in water ranging from 300 to 3,600 feet, and even on the slope of an underwater canyon ten miles off Point Loma. The division's activity reports record months of painstaking data gathering, aided by ingenious improvisations like the design and construction of an underwater tripod to hold a microphone, which listened to the sounds of numerous ships coming and going, at the entrance to San Diego Harbor.[64]

Of the many obstacles to accurate navigation, detection, and targeting that employees of the UC division laboratory overcame, one required the special talents of oceanographers: the sheer abundance and activity of sea life.

The ocean is alive. From schooling shrimp to migrating whales, sea life produces a constant background chatter of crackling, popping, moaning, and roaring sounds that confound efforts to hear the approach of enemy vessels. Recordings off the coast of San Diego County at the time contain a constant "cackling" sound.[65] Through many observations (often in the waters off the Scripps pier in La Jolla and during several visits to the tanks of sea life at Scripps aquarium), oceanographers and acousticians determined the din was the tiny clicking sound produced by a crustacean called snapping shrimp, *Crangon heterochaelis*, magnified millions of times as the creatures drifted in the offshore currents.[66] Similarly, the deep sound of a bottom-feeding fish called the croaker could confuse the operators of hydrophones and make it nearly impossible to

[64] University of California Division of War Research Bi-Weekly Report Covering Period July 27–August 8, 1942, 7.

[65] UCDWR Bi-Weekly Report Covering Period February 7–February 20, 1943, 1 and subsequent entries.

[66] UCDWR Bi -Weekly Report February 21-March 6, 1943, 1. Also Martin W. Johnson, "Underwater Sounds of Biological Origin," UCDWR Report U28, February 15, 1943. In a report several weeks earlier, *Crangon dentipes* had been initially targeted as the potential major sound source.

separate the sound of a propeller from the general background noise of the ocean.

Research to improve equipment and training prompted UCDWR scientists to take the next step in pro-submarine warfare: learning to reproduce the noise underwater, which enabled American submarines maneuvering in Japanese-held harbors to hide their own telltale noise under a cloak of artificial sea sounds.

Research farther out at sea led to the UCDWR discovery and identification of the Deep Scattering Layer, a horizontal layer of ocean roughly three hundred to four hundred meters deep that reflected sonar signals (especially those of early sonar models, typically transmitting at 24 kHz).[67] Listening to reflected signals, an operator could believe erroneously they indicated the sea floor. But there was an anomaly as well: The layer rose toward the surface at night and sank again during the day. Investigation (via deep trolling and countless readings) confirmed the theory that the layer is a band of water at which marine life small and large abounds. Plentiful fish and tiny creatures like plankton are enough to reflect acoustic waves. The rise and fall provided a clue: sea life in the layer rises at night to stay at a steady water temperature, and that temperature decreases after the sun goes down. Thus, sea creatures rise at night and create a shallower reflection.

The Deep Scattering Layer discovery resulted in greater calibration and accuracy of sonar's ability to detect submarines, and as with so many anti-submarine discoveries it also led to a pro-submarine idea to research density and other characteristics of the layer to help U.S. submarines elude detection.

Even farther out, the sea floor is composed of canyons and mountains and, except for relatively shallow coastal waters, the sea bottom was largely unmapped in 1942. Further, the composition of the sea floor—sandy, rocky, covered with organic material, or almost sterile—was all but unexamined. As a consequence, sound and radio waves echoed from or vanished unpredictably in the depths.[68]

---

[67] Robert S. Dietz, *Some observations on Operation HIGHJUMP* [sic], U.S. NEL Report No. 55, 7 July 1948. A footnote on Page 82 attributes the original discovery of the layer to C.F. Eyring, R.J. Christensen, and R.W. Raitt of UCDWR, and mentions the suggestion it be titled ECR layer on that account.

[68] In 2014, news coverage of the disappearance of Malaysian Airlines flight MH 370 stated the "fact" the ocean bottom was still 95 percent unexplored. A more accurate statement would focus on level of detail; over the years ocean mapping has resembled a picture coming into sharper focus. In 2014, Scripps Institution of Oceanography published a satellite-enabled map detailing sea floor objects larger than two kilometers high. "Just How Little Do We Know about the Ocean Floor?" *Scientific American*, October 9, 2014.

Fortunately for the Americans, Japanese coastal waters had been sounded by early echo equipment from 1930 to 1939, and these data were acquired before hostilities cut off communication. UCDWR technical clerks in the summer of 1942 undertook an intense effort to map coastal Japanese waters and match temperature conditions and thermocline data during seasonal and weather changes. By January 4, 1943, the group had completed a technical memorandum entitled "Sound-Ranging Conditions in the Japanese Area, Winter Season."[69] The Navy made charts—thousands of them—and prepared reports on submarine operating conditions while the American military fought across the Pacific.[70]

In the fall of 1942, UCDWR personnel completed an underwater map "showing the contours and zones of different bottom character in the approaches to Tokyo and Yokohama," potentially useful in locating "zones of concealment for submarines and zones where submarines could rest on bottom... The rocky walls of the submarine canyons suggest possible zones where bottom reverberation would interfere with submarine detection."[71]

The lakes

In the first years of the war, transducers developed for use in tracking submarines were tested and calibrated in San Diego harbor. Increasing boat and submarine traffic and the biological sounds discussed above made by snapping shrimp interfered with testing over time; as an acceptable alternative, access was acquired to Sweetwater Reservoir, a dozen miles due east of Point Loma, near Chula Vista.[72] The reservoir was deeper than the harbor and, lacking boat traffic, quiet, a perfect setting for recording different formulations and frequencies of crystal transducers. A barge was moored on the reservoir, allowing the scientists to conduct their research at appropriate water depths away from the shore. A

[69] UCDWR Bi-Weekly Report December 27, 1942—January 9, 1943, 3. Memorandum was U20 of January 4, 1943.

[70] Daryl Bottoms, Compiler. "World War II Records in the Cartographic and Architectural Branch of the National Archives," (Reference Information Paper 79, National Archives and Records Administration, Washington D.C., 1992), 39-40. Also, University of California Division of War Research, "Submarine Operating Conditions in the Western Pacific." 1 February 1946, 1-3.

[71] UCDWR Bi-Weekly Report October 4-17, 1942, 3.

[72] Sweetwater Dam was completed in 1888; the reservoir still supplies water for drinking and recreation to the San Diego area. Sweetwater Authority: http://www.sweetwater.org accessed April 29, 2021.

transmission line from shore provided power to the sound transmitter on the barge.

Activity reports beginning in early 1943 contain lengthy descriptions of calibration activity and testing of transducers, which were manufactured by private industry. For example, records from March 1943 detail the testing of fourteen transducers built by the Brush Development Company, intended for use in practice targets. Tests showed that while the units performed uniformly among themselves,

When ship traffic and the natural sounds of sea life in San Diego harbor prevented University of California acousticians from taking sensitive measurements to calibrate their sonar transducers, they set up a facility at Sweetwater Lake about fifty miles northeast of Point Loma for the purpose.

they weren't up to the standards written by the Navy. However, notes the log, Navy specifications were written for noisy San Diego harbor in 1942, and allowing for the difference between the harbor and the reservoir, the transducers would perform well under actual operating conditions. Revised specifications were duly sent to the Navy's Bureau of Ships to order operational units.[73]

The division's testing of transducers occupied its Sweetwater Lake facility full time. When the need arose for testing other technologies in quiet water, the Navy acquired use of El Capitan Reservoir in the Capitan Grande Reservation northeast

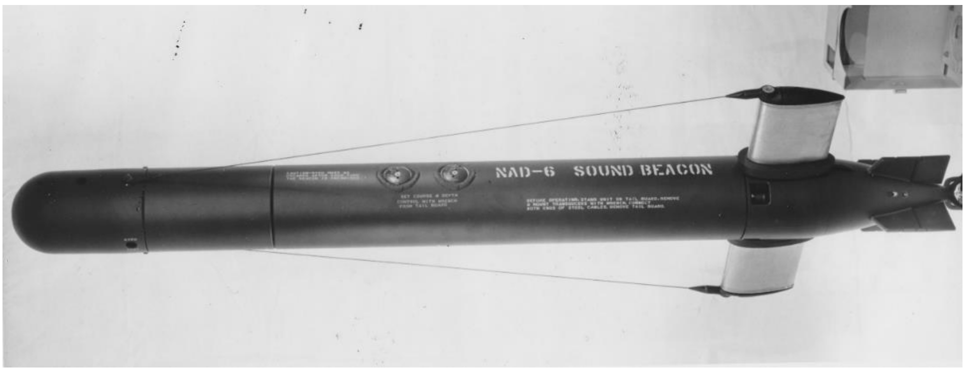
[73] UCDWR Bi-Weekly Report Covering Period March 7-20, 1943, 1.

of San Diego. Built in 1935, El Capitan was (and is) a large reservoir, with a maximum depth of 197 feet and a surface area of 1,562 surface acres. It was used for testing sonar decoys.

Sound beacon decoys

The Imperial Japanese Navy had echo-ranging equipment that was sufficient by 1942 standards, giving ranging data up to 3,400 yards. Its hydrophones could detect and give bearings for targets at 5,400 yards—more than 2.5 nautical miles.[74] Although American electronics technology surpassed Japanese development during the war, the enemy's ability to spot a submarine and surround it with depth charges was a significant threat:

> UCDWR was tasked with devising countermeasures, and came up with a variety of devices… the self-propelled NAD, was developed by the division beginning in May 1943. It resembled a small torpedo, and was designed to be launched from a submarine's torpedo tubes, from which it simulated an American submarine running at periscope depth. It carried a sonar repeater…that could capture a sonar ping and quickly retransmit the sound, jamming the signal…The later models could run at 3.7 knots for an hour, giving the mother ship sufficient time to dive and change course, eluding enemy ships as they followed the beacon.[75]



NAD-6 Sound Beacon Decoy

[74] Keith Wheeler, *War Under the Pacific* (Chicago: Time-Life Books, 1980), 98.
[75] Norman Friedman, *U.S. Submarines Through 1945* (Annapolis, Maryland: Naval Institute Press, 1995), 247.

Submarines could also hide from listening ears by taking advantage of the thermocline and other changes in water temperature. Working with Scripps Institution of Oceanography, UC scientists gathered and analyzed ocean sound reflection and refraction data using a device called a bathythermograph (BT). Scientists at Woods Hole Oceanographic Institution developed an onboard BT for submarines to take advantage of the Point Loma laboratory's findings.[76]

Other staff set to work on the behavior of electromagnetic energy in water. Their first important task was to join several weapons laboratories to improve the Mark 6 detonator in torpedoes. Through the early months of the war, submarine skippers had recorded frustrating patrols in which the torpedoes either exploded prematurely or failed to detonate.[77] The Navy's Bureau of Ordnance had designed the Mark 6 to detect the magnetic field of a surface ship and explode under its keel, the most vulnerable place on a warship's structure since hulls were heavily armored. In ideal conditions this worked, but in war, conditions are never ideal and rarely identical, and solving the mystery of the malfunctioning detonators fell to laboratories sponsored by the bureau.

Scientists discovered the problem (and therefore the solution) would be multidimensional: the magnetic field of a surface ship, which triggered proximity fuzes,[78] varies with geographical position on the globe. In northern and southern waters, it is almost a hemisphere; nearer the equator, the magnetic field flattens out. A torpedo armed and calibrated to explode directly under a ship in Alaskan waters might not detonate in the Sunda Strait between Sumatra and Java. Submarine crews would thus have to set the torpedo's running depth before launching. An unrelated problem with torpedo guidance systems caused a critical ten-foot error in depth running; soon skippers were setting their torpedoes to run "shallow," knowing that they would then run at the correct depth.[79]

The UCDWR biweekly reports of 1942 show continuous work testing the magnetic fuzes. Pilot models were designed and constructed in cooperation with the Naval Ordnance Laboratory at the Washington Navy Yard, which provided

---

[76] Friedman, *U.S. Submarines*. Also, various UCDWR reports.
[77] *War Under the Pacific*, 32-40.
[78] While modern dictionaries describe fuze as a variant of fuse, the term fuze refers to a device meant to trigger an explosion, while the latter generally referred to the obsolete "burning cord" type fuse. Fuze was also commonly used to distinguish an explosive trigger from the unrelated household electrical safety device (as in "fuse box"). Spellings in original sources are inconsistent; original spelling is retained in the citations.
[79] *War Under the Pacific*.

testing support. Sometimes the in-house tests were decidedly low-tech, suiting a weapon that must be durable and safe for its handlers. A report from 1942 documented typically robust experiments to determine whether impact or magnetic field would set off the fuze:

> Tests on a close proximity fuse have been completed, using a separate amplifier mounted on a table. The fuse itself is highly stable: sharp blows with a stick of wood did not trip the relay [part of the triggering mechanism]. Eight inches of wood were then piled on the nose of the fuse, and an iron plate dropped on to the wood; the relay tripped on every occasion. By increasing the gain, it was possible to trip the relay by waving a steel bar at a distance of four feet.[80]

Transducers

The division activity reports frequently recorded testing, calibrating, and otherwise experimenting with transducers, an essential component of underwater sensors. The electroacoustic transducer was the central technology of the subsurface Echoscope, which mixed a continuous acoustic signal with a continuous echo signal to determine the range and relative location of an object.

In the summer of 1942, the group responsible for testing echo-location equipment dubbed the project "COBAR" (Continuous Bearing and Range), partially for security reasons.[81] They set out to sea with barges and ships, including their workhorses USS *Jasper* (PYC-13) and the Scripps motor launch *Torqua*, towing underwater triplane targets and taking bearings. *Torqua* was outfitted with a retractable column that held as many as four crystal transducers for testing. By August 1942, COBAR could detect targets accurately to 750 yards. Transducer testing involved many variables: frequency ranges of COBAR signals, ocean conditions, and signal refraction. All were noted, logged, and brought back to division workspaces for analysis, with the aim, once again, of helping submarines

[80] UCDWR Bi-Weekly Report September 6–September 19, 1942, 9.

[81] An entry in the August 23-September 6, 1942 UCDWR report states: "Due to the fact that a large number of persons outside of NDRC and the Navy have some knowledge of the Echoscope, it appears desirable for this and other reasons to change the name of the project to COBAR." The entry specified inclusion in the COBAR category of devices producing a continuous signal indication and exclusion of those producing intermittent target indication.

identify and target enemy ships, to identify and avoid Japanese harbor defenses.[82]

A few months later, COBAR achieved a notable real-world test result when, as the record of December 1942 states, "A 30-in. mine used for experimental purposes had been lost in San Diego Harbor. After standard method [sic] of search and location had failed, the Mark VII installed on M.V. TORQUA detected the mine in about ten minutes. By taking cross bearings it was easily located and recovered."

An adaptation of the COBAR system first appears in a January 1943 report[83] identified as the Mark I PP1 Fampas. (No explanation was provided for the name, which did not seem to be an acronym.) It was cited as undergoing preliminary testing that showed encouraging results. Four months later, the improved Mark II Fampas with twenty filter channels (vice ten-line raster of Mark I) was introduced.[84] Size of the newer model was reduced by a factor of three, according to an earlier report, plus,

> The improvement in resolution and general appearance seems to be even greater than would be expected from the mere increase in number of lines. For harbor protection the device with 20 channels probably has adequate resolution. It has a range scale with a maximum of 1600 yards.

The following report (May 30-June 12, 1943) details a successful first trial on Barge No. 4 towed "beyond the 600-fathom line" outside San Diego harbor. In July, "in its first test under simulated battle conditions, the 20-channel electronic Fampas performed successfully."[85] Developers had mounted it on the *Torqua* and employed it to detect and track a submerged submarine. The equipment was able to maintain contact despite "full evasive tactics" of the sub, and advised its operators of the correct time to fire a weapon. Using the Mousetrap launcher aboard the vessel, two rounds of sub-caliber ammunition were fired. Navy officers from the West Coast Sound School who witnessed the runs stated full-caliber salvos fired at the same position and time would have hit the target submarine. (The officers were able to track visually a buoy towed by the submarine, which was operating at a depth of ninety feet. The Fampas operator could not see the buoy and depended entirely on his instruments to track and target the sub.)

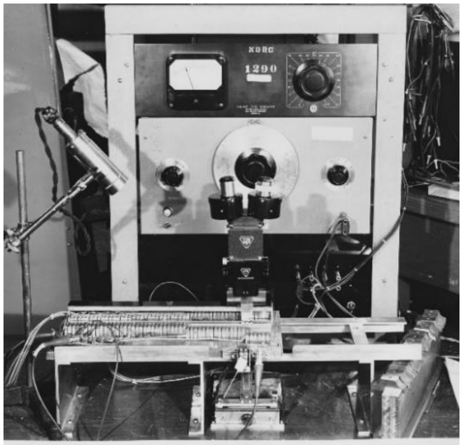
---

[82] UC Division of National Defense Research Bi-Weekly Report August 23–September 5, 1942, 7-8.
[83] UCDWR Bi-Weekly Report of January 24-February 6, 1943, 6.
[84] UCDWR Bi Weekly Report, May 16-29, 1943, 8.
[85] UCDWR Bi-Weekly Report of July 11-24, 1943, 7.

As an added benefit, it was found Fampas could be used as an excellent navigational instrument:

> While the TORQUA [sic] was passing out to sea through the submarine net barge, Fampas clearly showed the fixed portions of the net, the moveable portion, the two barges, and the gap between them. The TORQUA could have been taken through the gap entirely by Fampas observations without recourse to visual observation.[86]

Shortly thereafter, discussions were held on the equipment, during which it was decided that Fampas could be classified as a sonar: "The name Fampas will hereby and henceforward not be used and the device will be known as FM Sonar."[87]



Fampas was an early version of a sonar capable of detecting and tracking submarines.

---

[86] UCDWR Report, July 11-24, 1943, 8.

[87] UCDWR Bi-Weekly Report of August 8-21, 1943, 8. As detailed in Chapter 1, the term "SONAR" was coined by Dr. Frederick V. (Ted) Hunt, director of the Harvard Underwater Sound Laboratory. His acronym represented SONic, Azimuth and Range, suggesting an easily understood term similar to RADAR. The Navy changed his defining words to SOund NAvigation and Ranging. The term was first introduced to the California scientific community in the UCDWR report of October 31-November 13, 1943, announcing official Navy approval of the title, which "accords the field of underwater sound as streamlined and functional a name as the title of 'Radar' given to its younger sister field in electronics." The editor cited the Navy desire to "popularize the use of the new term within approved naval and civilian circles."

Additional runs against a submerged submarine were carried out, each ending with the firing of a single practice projectile from a Mousetrap launcher, almost all of which were "judged as good as those of similar attacks executed by West Coast Sound School ships attacking the same target." As a result of its success, the FM Sonar was deemed a potential merchant vessel protective device and work began immediately on a prototype.

Fampas equipment functions as passive sonar

The following report noted that the sonar's rotating receive and cathode-ray screen were able to detect torpedoes by their own noise at ranges greater than 2,000 yards and provide accurate bearings without any echoes from the targets. "This was accomplished without any alteration of the equipment, showing that Sonar can perform this listening function in addition to its normal one of echo-ranging."[88] In other words, the equipment could be used as a passive sonar.

The success of the FM Sonar prompted an official of the National Defense Research Committee to issue a set of proposals including study of it as potential sound gear for submarines. UCDWR's Sonar Group was tasked with a cooperative project with the Radio and Sound Laboratory to outfit a small boat with FM Sonar and COBAR to evaluate them in searching for submerged objects. The NDRC official also advocated the development of a "silent" fathometer.[89]

Near the end of 1943, the FM Sonar prototype was installed on USS *Semmes*, a flush deck destroyer of World War I vintage (DD-189 at the time) that was employed at the New London base occupied by the Columbia University Division of War Research (CUDWR) as an experimental vessel (AG-24). UCDWR engineers traveled to New London several times from late 1943 to early 1944 to install, maintain, and repair the equipment, which was employed on submarine tracking and attack trials there.[90]

---

[88] UCDWR Bi-Weekly Report of August 22-September 4, 1943, 7.
[89] UCDWR Bi Weekly Report of October 3-16, 1943, 9. Also, G.W. Downs, "'Silent' Fathometer." UCDWR Report SM98, 28 August 1943.
[90] UCDWR Bi-Weekly Report of December 12-25, 1943, 6.

At the same time, another FM Sonar suite was installed on the M.V. *Torqua* for a demonstration in San Diego to the Commander, Submarines Pacific and representatives of NDRC and CUDWR. Additionally, work proceeded on building another FM Sonar, this one slightly different than the previous models, to be installed on a boat from Submarine Division 41.[91]

The sonar installed on USS *Semmes* was based on the UCDWR-developed CP8 transducer. Despite heavy seas that battered the equipment, the sonar proved its value in between several short circuits caused by the damage. The editor of the biweekly reports noted wryly, "The CP8 transducer… has been returned to this laboratory after its hectic debut at New London, mechanically broken but acoustically triumphant." The tests showed the division's mechanical design innovations had overcome some of the crystal shortages by enabling a greater range of resonant frequencies in a given crystal.[92]

In San Diego, the FM Sonar installed on the submarine S-34 completed several sea trials; UCDWR personnel considered the performance to "leave something to be desired," but the commanding officer of Submarine Squadron 45 disagreed and recommended to Commander, Submarine Force Pacific that an FM Sonar be installed on the next fleet-type submarine to reach San Diego.[93] By the fall, the installations began on the fleet boats and the submarine squadron detailed six of its radio technicians to UCDWR for training on the sonar.[94]

The success of the division's FM sonar led to additional requests for installations and for training more personnel. An effort to develop an appropriate manual to detail sonar operation and maintenance via text and still photographs proved nearly impossible, so late in 1944 it was determined a better course of action would be to produce a motion picture.

The final UCDWR biweekly report, covering the period from late January to early February 1945, advised that FM sonars had been installed on seven of the nine submarines requested, and the others would be completed by mid-March. It also reported, "An FM Sonar, arranged to operate much like Delta Cobar, has been set up at Sweetwater [Reservoir] for measurement of target strengths."[95]

---

[91] UCDWR Bi-Weekly Report of December 12-25, 1943, 6.
[92] UCDWR Bi-Weekly Report March 5–March 18, 1944, 3.
[93] UCDWR Bi-Weekly Report of March 19-April 1, 1944, 8.
[94] UCDWR Bi-Weekly Report of September 3-16, 1944, 6.
[95] UCDWR Bi-Weekly Report January 21-February 3, 1945, 7.

The need for a variety of transducers for FM sonars and other applications was great, but the supply of necessary materials was short. UCDWR established a laboratory to build transducers and their accompanying equipment. Working with other Navy laboratories and private companies, division personnel proposed, designed, and tested hundreds of improvements in transducers and accompanying equipment. Acquiring a ready supply of parts for tests proved difficult. Entry after entry of the division activity reports records a discouraging shortage of crystals, the heart of transducers at the time. For nearly two years, the transducer group was forced to build special transducers by trial and error. Not until October 1943 could the activity report editor note with relief,

> The impending disaster of an inadequate supply of Rochelle salt crystals has now been partially dissipated. Recent action by the Bureau of Ships has insured [sic] the receipt of sufficient crystals for the most pressing work at hand, and the group is again able to discharge its obligations.

The ingenuity of UCDWR scientists shows in the report, noting the shortage of special crystals resulted in the discovery of a technique for fabricating one long crystal out of two short ones (length of the crystal was a factor in testing different frequencies) using a jig and hot metal strip to fuse two crystals end-to-end.

The broad and exacting work required the talents of a host of different people: mechanics, welders, construction workers, and more, including a job frequently performed by women employed by the division with the utilitarian-sounding title of "computer." As noted above, Barbara Root and a number of other women recruited by the division had significant background and capabilities in mathematics. The term had nothing to do with the electronic equipment found ubiquitously today, but rather was a term for "one who computes." Employees at the weapons lab that was one of the two foundations of today's NIWC Pacific were also called "computers," and were women. This phenomenon is now widely recognized based on its dramatic portrayal in the Hollywood production *Hidden Figures*, itself based on a book of the same name.[96]

The QLA sonar

One of the most significant and longest-employed technologies produced by UCDWR was the QLA, an FM-based scanning sonar that resulted from the

[96] Margot Lee Shetterly, *Hidden Figures* (NY: William Morrow, 2016).

complex development process summarized immediately above. A scanning sonar is capable of continuous wide-ranging search, and can detect smaller objects than the war's earlier acoustic devices were able to hear. The QLA presented a breakthrough for the operator in that it could present its echo in both audible tones and visual signals—spots on an oscilloscope device similar to the spots on a radar scope.[97]

Although UCDWR engineers desired better performance from an FM sonar they installed for testing on a submarine, Fleet personnel were extremely pleased with that performance and advocated installation on all their boats.

The sonar evolved from an earlier project called Echoscope, which was tested successfully to determine target range, but had both material and research shortcomings. As the undersea conflict shifted from anti-submarine to pro-submarine warfare, engineers from the UC division adapted Echoscope technology so "its outputs could be displayed on a cathode-ray tube"[98] and later, as noted above, presented audibly as well. (The UCDWR development team, headed

[97] "Naval Sonar Chapter 14: Submarine Sonar Equipment," Historical Naval Ships Association, accessed January 5, 2015, http://archive.hnsa.org/doc/sonar/chap14.htm.
[98] *Fifty Years of Research and Development*, 12.

by Art Roshon and Kenneth Wyckoff, was categorized in several publications as the "Sonar Wizards."[99])

QLA sonar increased submarine crews' awareness of their environment, and thus ability to fight, with significant improvements in range finding (distance to target), bearing (where the target is in relation to the submarine), and target motion (in which direction, and at what speed, the target is moving). By filtering and analyzing the changing frequencies of echoes, the QLA used the Doppler effect—the changing frequency of sound waves over distance—to render an accurate location, speed, and bearing of enemy ships. This information was used to set the direction and speed of torpedoes, making them more likely to run true to their target. The QLA's later designs managed to isolate the signals from transmitting and receiving components, almost eliminating "crosstalk" between signals.[100]

Testing of sonar was almost continuous from 1943 to the end of the war, and as usual, the testing uncovered practical problems to solve. For example, in July 1943, substandard performance of a previously working model was found to result from transducers being battered within their housing by a submarine's motion against heavy seas.[101] During the same summer, staff members analyzed ship's reports of eighty-two attacks that were unsuccessful because of poor sonar operation, determining that half of the failed attacks were the result of operators either following false contacts or being fooled by stern wakes.[102]

The combined effect of excellent sonar and effective countermeasures enabled U.S. submarines to sail the inland waters of Japan with deadly effectiveness late in the war. Despite the presence of Japanese mines and sub-hunting craft, so much military transport was sunk that by late 1944, few targets were left on the seas except those near the Japanese homeland. The deployment of QLA sonar on U.S. submarines dealt another heavy blow to Japanese shipping in the following year; its accurate mine detection enabled fleet boats to navigate through Japanese waters. As an example, in May 1945, nine submarines led by Commander E. T. Hydeman on the USS *Tinosa* (SS-283) sailed from Guam. They rescued ten survivors of a downed B-29 bomber, then ran through the heavily

---

[99] Space and Naval Warfare Systems Center Pacific *News Bulletin: 75th Anniversary Special Edition*, 2015, 66.

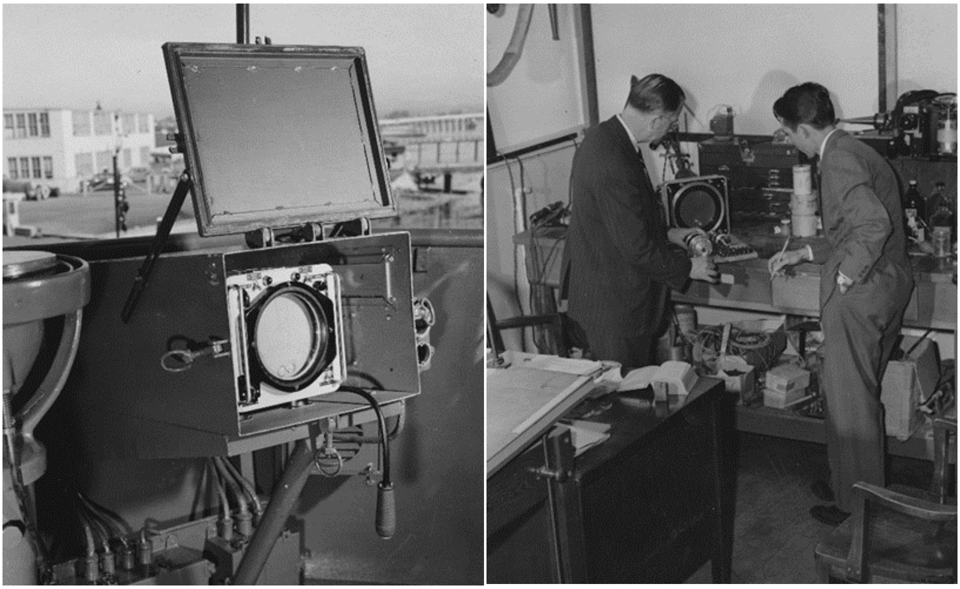
[100] *Design and Construction of Crystal Transducers*. "Crosstalk," incidentally, was a common term in electrical engineering of the time; only later did it acquire its conversational meaning.

[101] UCDWR Bi-Weekly Report July 9–22, 1944, 7.

[102] UCDWR Bi-Weekly Report August 20-September 2, 1944, 14-15.

mined Tsushima Strait, plotting mines as they went. On station, they proceeded to destroy twenty-eight merchant ships, a terrible loss to the fast-shrinking empire.[103]

The QLA, the first several of which were built by UCDWR personnel before a contract was established for mass production, was designed for detection of submarines and mines, and for navigation close to a detected submarine. The sonar would provide perhaps its greatest value shortly after the war, when it was employed in the early submarine under-ice navigation operations.



The QLA sonar would prove a key factor in U.S. submarine operations against enemy subs near the end of World War II. Prominent developers were (right photo, l-r) “sonar wizards” Kenneth Wyckoff and Art Roshon.

Radar

Throughout the war, UCDWR staffers tested and improved the engineering details of radars on ships, devising enabling technologies to make radar more effective. For example: in support of one of the Navy training commands in San

[103] Clay Blair, *Silent Victory: The U.S. Submarine War Against Japan* (Annapolis, Maryland: Naval Institute Press 2001), 863.

Diego, division scientists in 1944 designed an "automatic plotting feature" to bypass the existing system of passing radar information verbally (via telephone) from the equipment operator to the sailor creating a plot of what the data revealed. Such a system had multiple potential failure points, from misinterpreting spoken words to manual plotting with a drafting machine. It was impossible to keep track of more than four target ships, a tactical danger for a destroyer or submarine in the confusion of battle.

The Automatic Target Plotter used a system of lenses, mirrors, and cams to project spots of light onto the Dead Reckoning Tracer (DRT) table, used by submarines and ships to map surrounding ship activity. Results were more than satisfactory, notes the biweekly report:

> It quickly became apparent that the DRT plotting operator was able to plot the positions of target ships (as well as his own ship) faster than a skilled Radar Operator could supply the information… This is not surprising, for the plotter need only mark the position of the center of a stationary and sharply defined light spot upon receiving a buzzer signal from the Radar Operator.[104]

In this as in all of their work, division personnel demonstrated an ability to see technological problems in their operational context. A good radar might be made excellent in the lab through technology breakthroughs, but it might also be improved dramatically in the field by eliminating a mundane point of failure, like operators shouting instructions to each other.

Racons, radar beacons that function for homing and navigational purposes, were developed by UCDWR, and a racon station was built on Point Loma. By broadcasting radar beams in high and low frequencies, a racon device enables airborne instruments to orient themselves to the beam's location, providing a similar reference to a plane that a navigation buoy or lighthouse provides to a ship.

Teaching and training

Technology improvements required training operators of advanced devices, from hydrophones to sonar to radar and other targeting systems. As noted above,

[104] UCDWR Bi-Weekly Report covering period July 23-August 4, 1944, 12.

NRSL managed training of military personnel in radar operation, although that was not an assigned lab function. UCDWR, working on projects to design and develop new sonar equipment, was required by its Office of Scientific Research and Development contract to train potential sonar operators. In doing so, they designed numerous devices for simulating equipment as it would be used in battle.

Enlisted personnel and officers learned to operate acoustics equipment in the division's training facility through recordings. They practiced differentiating, for example, the low thumping sound of a transport's propellers and the faster, swishing sound of a destroyer's screws. An early UCDWR report states,

> In the spring of 1942 a simple portable model of a machine termed the Primary Bearing Teacher was developed by UCDWR. This device was exhibited... at a joint conference of the NDRC Committee for the Selection of Training of Sound Operators and interested Naval officers… In the discussion which followed, Lieutenant Commander Rawson Bennett suggested that the Primary Bearing Teacher had the mechanical elements needed in a Primary Listening Teacher, and, in view of the large expected fleet expansion, it would be highly desirable to develop such a listening teacher.[105]

UC personnel developed three models for comparison, sending them for evaluation to the Submarine School in Connecticut and the Fleet Sound Schools in Key West, Florida, and San Diego. After trials in actual training classes, one was selected with necessary requisites and UCDWR personnel built ten models of that design and distributed them to training schools in accordance with Bureau of Ships direction. Schematics were turned over to private industry for production.

One of the division's creations in 1943 was the "Conning Teacher," which included the following exercises for potential submariners:

a) estimation of approximate target angle
b) setting a collision course
c) developing a Seaman's Eye
d) depth charge attack
e) urgent attack at close range
f) forward thrower attack (submarine on straight course)
g) forward thrower attack (submarine evading)
h) depth charge attack (submarine evading)
i) conning officer and sound officer teamwork
j) unrestricted operation.[106]

---

[105] Henry E. Hartig and George A. Brettell, Jr., "Primary Listening Teacher," UCDWR Report U57, April 30, 1943, 1.
[106] UCDWR Bi-Weekly Report June 27–July 10, 1943, 8.

UCDWR personnel designed, developed, and built both Primary and Advanced Bearing Teachers to instruct students in the fundamentals of operating, reporting, and listening for Doppler. Likewise, there were primary and advanced teachers for listening, shipboard anti-submarine sonar and attack training, and shipboard sound operator training. These devices and training instructions in sonar, radar, fire control, torpedo control, and other combat functions provided the Navy well-trained officer and enlisted personnel to operate essential devices on its surface and undersea platforms.

Division psychologists also initiated what would be called "human factors" research, testing for necessary skills and individuals who possessed them. Researching the physical and psychological qualities of the best operators, they aided improvements in hydrophone and sonar performance by studying the human ability to discriminate among the many sounds in the sea. One example:

A possible solution for the growing shortage of qualified candidates for sound operators may be found in using enlisted personnel suffering from moderate myopia or short-sightedness. An investigation already underway has indicated that many men who fail to pass a vision test at 20 feet can easily pass one at 18 inches. Most of the work of a sound operator is done with all instruments within this latter distance.[107]

In addition to other resources, the division maintained a group of technical information specialists—writers, photographers, graphic artists—to produce the many reports and other publications created by the division and by the Navy laboratory with whom they shared facilities. A similar group at the division's New York office prepared large numbers of equipment maintenance manuals.[108]

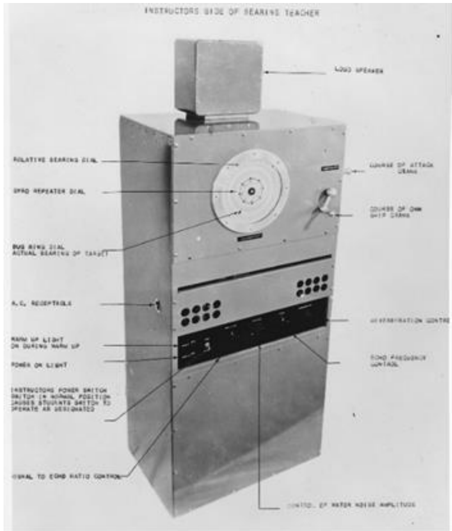
The separation above of the U.S. Navy Radio and Sound Laboratory and the University of California Division of War Research is purposeful, in that previous histories have posited a joint relationship that did not exist. Numerous quotations in a large number of reports and publications demonstrate clearly the two organizations existed as separate entities, with different management teams, different sponsors, and complementary but varying requirements.

---

[107] UCDWR Bi-Weekly Report September 19–October 2, 1943

[108] UCDWR Bi-Weekly Reports June 25-July 8 and July 9-22, 1944, 6 & 8 respectively; July 23-Aug. 5, 1944, 17.

That said, it is also patently clear the two organizations belied the much later arm's-length-or-greater relationships of Navy commands and contractors working for or with them. Throughout the periodic reports (an interesting illustration of distinct differences: NRSL's reports are "biweekly"; UCDWR's are "bi-weekly"), there are statements of close working relationships, teaming on a project led by one with the report written by the other. The two shared equipment, lab facilities, and boats, seemingly with none of the formality, document-generating, and cost-charging that is the hallmark of later government-contractor relationships. In fact, one monthly progress reports states the goal succinctly: "Collaborate with the U.S. Navy Radio and Sound Laboratory at their request or that of the Bureau of Ships on any problem which has been assigned to them by the Bureau of Ships."[109] The substantial war contributions achieved on Point Loma were the result of two sets of people working separately and often together to get the job done.



The instructor, positioned at the back of the Bearing Teacher, could observe the trainee's actions and provide appropriate feedback.

Grace under fire: Harald Sverdrup and Walter Munk

Before closing out the narration on NRSL/UCDWR significant contributions

[109] UCDWR Sonar Devices Monthly Progress Report, July 1945, Series II, "Task No. 8," ii.

to the successful war effort, it is essential to narrate a story of loyalty and scientific achievement overcoming war hysteria and bad judgment. It is an essential story because, as stated by a knowledgeable expert, thousands of American military personnel would be dead had it not occurred.

Thanks principally to the Scripps family of newspaper fame, the San Diego Marine Biological Association was formed in September 1903 to conduct "a biological and hydrographic survey of the waters of the Pacific Ocean adjacent to the coast of Southern California…"[110] The substantial financial and enthusiastic personal support of E.W. Scripps and his half-sister Ellen B. Scripps propelled the fledgling scientific institution, now bearing their name, to acceptance in 1912 as a distant outpost of the University of California, less than forty years old and with a single campus. It would be almost fifty years before San Diego hosted the seventh UC campus, up the steep, winding hill from Scripps Institution of Oceanography.

Around the mid-point of that half-century, the second director of Scripps, Thomas Wayland Vaughan, invited Dr. Harald Ulrik Sverdrup of Norway to succeed him, at least partially at the recommendation of a fellow Norwegian oceanographer. Sverdrup accepted a "temporary" appointment in 1936, but when Germany invaded his native land four years later, he asked it be made permanent. Shortly thereafter he, his wife, and daughter applied for American citizenship.

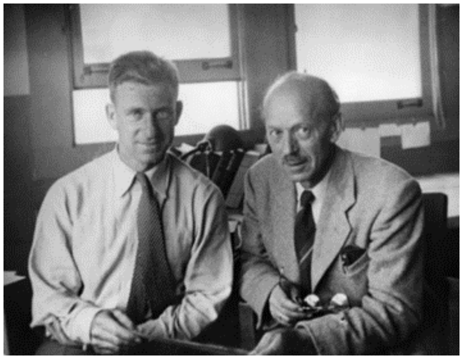
Sverdrup was five years into his aggressive expansion of the institution when the University of California established its Division of National Defense Research (later UCDWR), headed initially by UCLA's Vern Knudsen. Although he had an institution to manage, Sverdrup, who had often conferred on academic matterswith Knudsen, coordinated a carpool to bring himself and three other scientists (Eugene LaFond, Francis Shepard, and E.O. Emory) to the NRSL/UCDWR complex on Point Loma every morning to participate in the UC war effort. On March 1, 1942, he failed to appear; the FBI had pulled his security clearance.[111]

---

[110] Helen Raitt and Beatrice Moulto, *Scripps Institution of Oceanography—First Fifty Years* (The Ward Ritchie Press, 1967), Appendix B, as quoted in: Robert A. Knox, Ph.D., "*Mare Incognitum*." *Mains'l Haul,* Vol. 48, 3 & 4, 9. See the *Mains'l Haul* article for an excellent summary of Scripps' history.

[111] For a detailed account of the incident based on documents retrieved via the Freedom of Information Act, see Walter Munk and Deborah Day. "Harald U. Sverdrup and the War Years," *Oceanography*, Vol. 15, No. 4, 2002, 1 and 12.

Dr. Walter Munk (left) and Dr Harald Sverdrup



For the purposes of this history, suffice it to say that a long series of typical war-time events—glowing affirmative endorsements by nationally known scientists overturned by vague charges of disloyalty from often anonymous "concerned citizens"—brought into question the advisability of trusting national secrets both to Sverdrup and his student, Walter Munk.

Munk, a California Institute of Technology graduate, had been accepted as a doctoral candidate in 1940 by Sverdrup. Given the world situation, he shortly joined the Army, but at Sverdrup's request was given an honorable discharge and directed to work as a civilian oceanographer at the Point Loma complex.

Despite the ongoing investigations and serious allegations against them, Sverdrup and Munk continued to support the war effort, the latter requested by the Army Air Corps to come to Washington to assist in ocean swell forecasting for a planned troop landing on beaches in North Africa. Munk worked for a month collecting and analyzing data, and then said it would require the unique experience of his mentor, Sverdrup, to complete the forecasting capability. Sverdrup came immediately and spent most of October 1942 working on the problem with Munk, while both unknowingly were under twenty-four-hour surveillance as potential spies. On November 10, after the successful North Africa landings (which may or may not have resulted from the prediction work of Munk and Sverdrup), both men were "cleared" of various disloyalty suspicions and the FBI ended surveillance.

Nevertheless, four days later Munk was denied employment "with prejudice" and the next day Sverdrup's Army Air Corps employment was terminated.

Finally, on January 16 (Munk) and January 19 (Sverdrup), 1943, both were cleared of any disloyalty and authorized to resume their work on war efforts requiring security clearances. On February 9, 1943, the former Army Air Corps project was turned over to the Navy, and the Bureau of Ships professed confidence in Sverdrup. The two men returned to San Diego, where they developed and presented weather and wave prediction courses to two hundred Navy, Army, Air Force, and Marine officers, who would be the ones to plan the landings in Sicily and Normandy and on the islands of the western Pacific.

Sverdrup's final return to grace required the substantial intercession of Commander Roger Revelle. Sverdrup led Scripps for several years after the war; in 1948 he returned to his native Norway to continue his oceanographic research. Munk later was appointed to the Secretary of the Navy Chair of Oceanography.

Thanks to the efforts of Walter Munk and Harald Sverdrup, despite suspicion and harassment, planners of beach landings were able to predict with some accuracy the days and times of unacceptable surf and swell conditions that would have taken the lives of those coming ashore before reaching the beach. No doubt many of those soldiers and Marines still died, but did so heroically facing the enemy on the beach, and not in the cold, dark, inexorably choking grasp of the sea.

In his 1965 book, Blair Kinsman summarizes, "… there are some thousands of World War II veterans alive today who would have been dead in the surf had Sverdrup and Munk not done their best with what they had."[112]

Turning the tide

The Battle of Midway in June 1942 marked the extreme eastward progress of the Japanese Empire, but its conquests still spanned the western Pacific across a 5,500-mile arc from Kiska, Alaska, to Singapore and beyond. U.S. military forces would fight more than a thousand days after Midway. American sailors and Marines needed the scientific and technical expertise of the Navy's research laboratories and their university partners to give them every possible advantage in that combat, and that included more lethal weapons than sonar and hydrophones.

Those weapons—rockets, torpedoes, and other devices—were the products of scientists, engineers, and Navy personnel associated with the California Institute

[112] *Wind Waves: Their Generation and Propagation on the Ocean Surface* (Englewood Cliffs, NJ: Prentice Hall, 1965), 321.

of Technology and the Naval Ordnance Test Station (NOTS), working in the busy urban environment of Pasadena and the desolation of the Mojave Desert. As will be discussed at the end of this volume and continued in the second, significant portions of the weapons laboratory would merge with the electronics laboratory to form a single organization. The merger would result in the full-spectrum Navy ASW capability envisioned many years earlier by one of the towering figures of Navy R&D in both locations—Bill McLean. But first there was a war to win.

Eugene C. LaFond

Washington native Gene LaFond arrived in San Diego with his family as a teenager. Earning a chemistry degree in 1932 from San Diego State College, he began working as a technical assistant at Scripps Institution of Oceanography the following year. (Fellow San Diego State student Katherine Gehring was hired as a chemistry lab assistant there first, and alerted him when a similar position opened. They married in 1935, and she remained with him as wife and coworker until he died.) Accepted as a graduate student in 1936, he attended classes at the University of California in Berkeley, UCLA, and Scripps, where he became an oceanographer in 1940.

Many Scripps scientists at that time volunteered or were "sent down" from La Jolla to the anti-submarine research organization managed by the University of California on Point Loma. Eugene LaFond was its tenth employee. He was one of the scientists who carpooled to Point Loma with Scripps director Harald Sverdrup. Employed, as were most of his colleagues, in studying underwater acoustics, "Afternoon Effect, Its Applications to Sound-Ranging Charts" was one of the first of his multitude of papers. (As early as 1962, the lab newspaper reported publication of his one hundredth report.[113]) Eugene had the formal job of assistant oceanographer; in addition to raising their two boys, Katherine translated scientific documents from German and collaborated with Eugene on his research.[114]

When the war ended and the university lab closed, LaFond participated in

[113] U.S. Navy Electronics Laboratory *Calendar*, 2 November 1962, 4.
[114] Eugene and Katherine LaFond, interview conducted by Brian Shoemaker in San Diego, February 27, 2000.

Operation Crossroads, the two atomic bomb tests at Bikini Atoll, conducting environmental tests of the water after the explosions.

Eugene C. LaFond

Returning to San Diego, LaFond began his lengthy career at the Navy laboratory on Point Loma, participating for four years in scientific cruises to the Arctic aboard submarines and ice breakers. A Fulbright Grant sent him to India in the early 1950s, where he was instrumental in establishing that country's oceanography program. He was professor of oceanography at Andhra University (which granted him an honorary doctorate), participated in the International Indian Ocean Expedition, and conducted research and teaching cruises in the Bay of Bengal. He served a year as deputy director of the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Office of Oceanography.

His years at the Point Loma lab included two landmark projects: the design, engineering, and erection of the Oceanographic Research Tower to conduct that research *in situ*; and the thermistor chain, a 900-foot-long sensing device to study temperature layers by recording depth-vs.-temperature "lines" across large ocean areas. He also participated in Dive 84 of *Trieste* to investigate seafloor currents.

4

The War Years in the Desert

"Germans Beat Us to Punch On Rockets, Old Weapon We Have Long Neglected," proclaimed a headline in a Pittsburgh newspaper in November 1943, one of many running the same story.[1] The author, Major Alexander de Seversky, was a Russian aviation pioneer who overcame a series of physical difficulties to become a World War I flying ace. Attached to the Russian naval mission to the U.S. during the Bolshevik Revolution, he decided to stay. Volunteering to serve the U.S. War Department as a pilot during the final months of World War I, he later invented hundreds of new devices for the aircraft industry. His title of "major" came from his commissioning in 1928 into the Army Air Corps Reserve.

De Seversky's book on the importance of air power,[2] appearing only a few months after the Japanese attack on Pearl Harbor, was a highly influential text as well as a New York *Times* bestseller, advocating such forward-thinking strategies as an independent U.S. air force and development of long-range bombers.

The newspaper article reported on German development of rockets. Without mention of the facility, it referred to work done at the secret base at Peenemunde on the Baltic coast, where the German army had gathered a large group of technical personnel augmented by forced laborers from concentration camps to pursue weapon development. Their efforts resulted in the feared V-1 and V-2 rockets. The basic message, stated halfway through the article, was, "Since it is not a basic invention, how effectively any nation will exploit the known rocket principles and possibilities will be in direct proportion to the time, energy and creative brains invested in research and experimentation."

Whether de Seversky was aware of it is unknown, but at the very time he was

---

[1] Pittsburgh *Post Gazette*, November 4, 1943, 23. Newspapers across the country featured de Seversky's article with similar headlines ("Nazi's New Air Rockets Caught Our Side Napping").

[2] *Victory Through Air Power* (New York: Simon & Schuster, 1942).

writing his newspaper article on the importance of rockets, earth-moving equipment was thundering across the California desert, scraping out ranges for test-firing of rockets being developed by professors-turned-weaponeers at the California Institute of Technology in Pasadena. Only three months before, Dr. Charles Lauritsen, who was in charge of the effort, had been flown over that desert by a Navy pilot and spotted, as in a wish-fulfilling dream, thousands of square miles of basically uninhabited desert with a remarkable air field anomalously positioned in the midst of it. Collaborating with a naval officer he had met during a weapons test, Commander Sherman Burroughs of the Navy Bureau of Ordnance, the pair would initiate the creation of a new Navy testing organization to revolutionize research and development of air-dropped weaponry.

It was not the Russian-turned-American aviator's articles that provided early emphasis to that research and development, but rather the disaster hidden behind one of the most notable victories in the history of the U.S. Navy.

On June 4, 1942, as the Battle of Midway heated up, three squadrons of Navy and Army TBD torpedo aircraft, fifty-four planes in all, attacked the Japanese carriers *Akagi, Hiryu, Kaga,* and *Soryu,* armed with Mark 13 torpedoes. Most were obsolete Douglas Devastators, and only seven of those forty-one Devastators returned, their ranks decimated by Japanese fighters. Not one of the Mark 13s they flew low and slow to release exploded successfully against the hull of an enemy ship.[3] Fortunately, several waves of Douglas Dauntless dive bombers followed the Devastators. When the action ended, Japan had lost four of its carriers and several surface ships. Midway was a clear victory for the U.S. Navy, which the enemy expended substantial effort to hide, but the failure of one of the Navy's first-line weapons cost the lives of many naval aviators with absolutely no impact on that enemy. That failure had to be addressed immediately if the single victory were to be followed up appropriately to turn the tide. The scientists and engineers at Caltech had work to do beyond the rocket designs they were already conceiving.

Torpedo improvement

In the early 1920s, the Navy had restarted its manufacturing lines at Newport, Rhode Island, to produce American-made torpedoes in versions that could be

---

[3] Alvin Kernan, *The Unknown Battle of* Midway (New Haven and London: Yale University Press, 2005), Preface.

launched from surface ships and submarines, and from the air. The steam-driven Mark 13, the Navy's first torpedo specifically developed for aircraft launches, was judged ready for operational use in the summer of 1930. The weapon was 22.5 inches in diameter and 13.5 feet long, allowing its use from aircraft, with a range exceeding 6,000 yards.[4] Several months later, elimination of the carrier-based aircraft squadron that would carry the weapon resulted in a halt to production. Subsequently, the Bureau of Aeronautics pulled its support in favor of a thousand-pound torpedo for aircraft weaponry.

The Bureau of Ordnance, on the other hand, maintained its belief in the Mark 13, and with the start of World War II initiated focused production that would result in 17,000 of the torpedoes, which then operated so disastrously at Midway.

Commander Sherman Burroughs, who survived that battle when many of his squadron members and friends did not, was rotated ashore and assigned to the Bureau of Ordnance. In an interview several decades later, he commented on his own feelings, and those of fellow aviators, after the weapon's dismal performance:

> I was influenced greatly by our feeling of frustration, which a lot of people felt. The torpedoes we had didn't do anything at Midway. Nobody knew what happened to the torpedoes that were dropped; we sent out 43 torpedo planes from the carriers, and as far as anybody knows there wasn't a single hit registered, and all but about three planes were shot down… The torpedo problem was a very frustrating thing to all torpedo pilots… [5]

His conclusion: the "system of developing aviation ordnance was inadequate."

The task of finding a solution was assigned to the California Institute of Technology, already busily pursuing efforts, discussed below, to develop rocket technology. In response, a group of professors was dispatched to a Caltech facility at a reservoir backed up behind a dam to work the Mark 13 torpedo problem.

Morris Dam test range

On May 26, 1934, former president Herbert Hoover dedicated Morris Dam, built by the City of Pasadena Water Department and named in honor of Samuel B.

---

[4] Louis C. Gerken, *Torpedo Technology* (Chula Vista, Calif.: American Scientific Corp., 1989).

[5] Rear Admiral Sherman E. Burroughs, China Lake interview, November 4, 1966, 16.

Morris, its chief engineer and general manager.[6] Eighteen miles east of Pasadena, on the edge of the city of Azusa, the dam created a reservoir in the San Gabriel Mountains, running in serpentine fashion from southwest to northeast with a high peninsula jutting into the reservoir near its midpoint. A plaque on the dam anticipated that "this reservoir will later be used by the Metropolitan Water District of Southern California as a storage unit for Colorado River water." It did not predict the reservoir would become an essential test area for torpedoes.

The Morris Dam facility represented an important resource for Caltech, later for its general successor the Naval Ordnance Test Station, and for succeeding Navy centers discussed in this history, until it was phased out and shuttered in the 1990s.[7] Several years before the Mark 13 team arrived there, Dr. Max Mason, one of the three Caltech Council on Defense Cooperation founders, had initiated an Office of Scientific Research and Development-directed program in August 1941 at the dam. He was studying projectiles (throw-ahead ordnance) entering and passing through water, as well as observing fuze functioning under water. These efforts were on behalf of the Mousetrap launcher, the Caltech adaptation of the British Hedgehog, and the various rockets developed for that launcher, discussed below. Initially pursued on a separate contract from the principal rocket development work headed by Charles Lauritsen, in June 1942 this effort was combined with Lauritsen's program.

One of the principal challenges in the work pursued by Mason and his associates was development of a fuze for the anti-submarine rockets.[8] Proximity fuzes had been under development since World War I, but they were of little value in the context of the undersea environment. The Navy required a fuze that would only detonate when the weapon hit a target, because an unsuccessful strike or misfiring fuze underwater would disturb sonar readings for some time, conceivably "hiding" the enemy submarine long enough that it could escape. For some months, Mason's team studied existing fuzes, hoping to find one that would work for their purposes with Mousetrap-launched projectiles. Unfortunately, available fuzes were designed for artillery shells; they were armed when the shell was fired and began rotating as it sped toward its target. Both the setback that

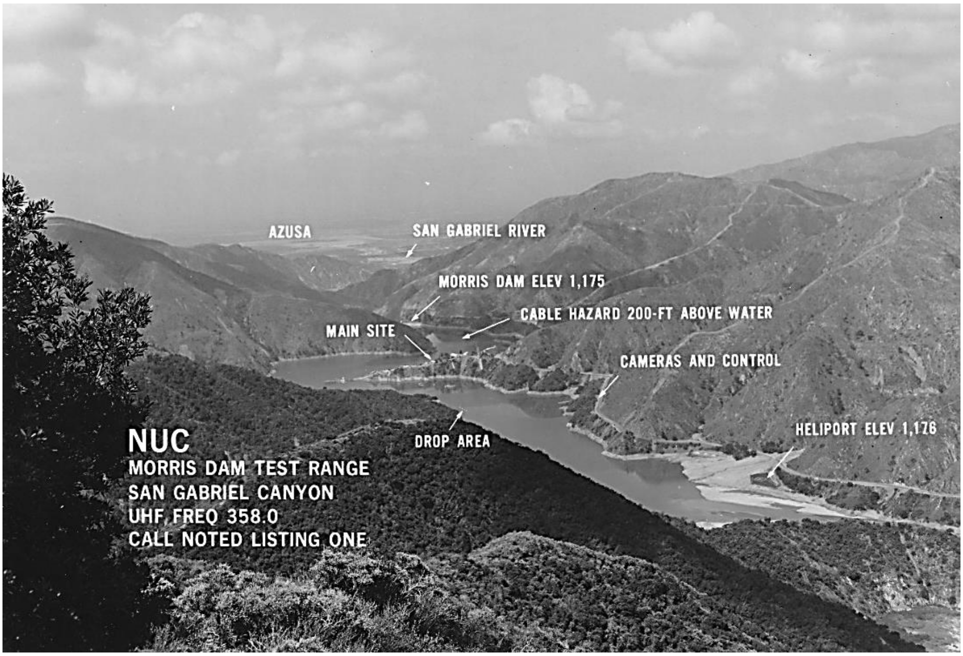
---

[6] Morris Dam plaque, 1934.

[7] The process of shutting down a test range in a lake that had seen thousands of test weapons fired and dropped into it obviously took a lengthy period. See Volume II for details.

[8] As detailed in a footnote in the previous chapter, the term "fuze" refers to a device meant to trigger an explosion, rather than the unrelated household electrical safety device (as in "fuse box").

occurred with the firing and the rotation, while significant for an artillery shell, were forces of no appreciable magnitude in the launch of a rocket.



Caltech professors turned weaponeers set up a range in the Morris Dam reservoir early in World War II to test projectiles to be employed with the Mousetrap launcher.

Stymied by existing technology, the team designed and developed a new fuze, which armed itself based on build-up of hydrostatic pressure as it hit the water. The charge would detonate on contact with a submarine's hull.[9] Calling it the Hydrostatic Impact Rocket fuze, Caltech ordered production of 30,000 of the original design; a subsequent design was standardized and mass-produced.[10]

[9] Conway W. Snyder, "Caltech's Other Rocket Project: Personal Recollections," *Engineering and Science*, Spring 1991, 5. Among other contributions, Snyder designed the HVAR motor, replacing the single nozzle with eight smaller nozzles. The center propulsion nozzle was replaced by one designed to blow out if pressure got too high, substantially reducing potential for an explosion and allowing its use in higher temperature climates.

[10] Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 1: Sailors, Scientists, and Rockets* (Washington, D.C.: Naval History Division, 1971), 132.

Proximity fuzes

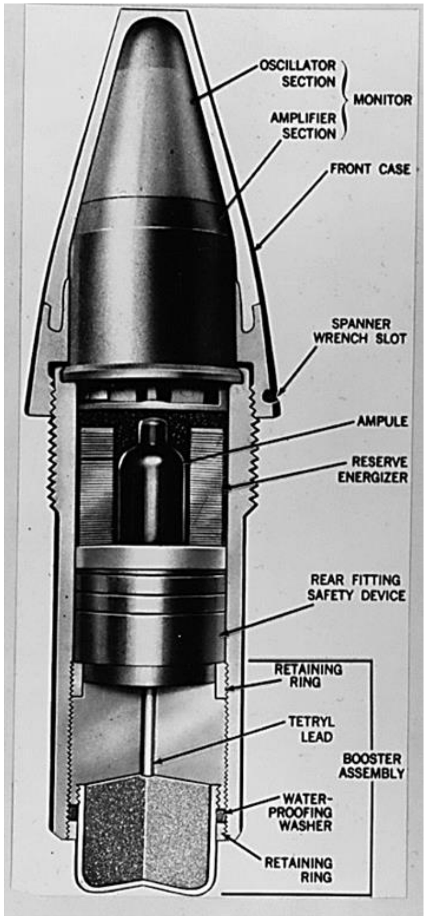
While they were of little use in the undersea/anti-submarine role, proximity fuzes were of substantial value in other applications. During his time in Washington, D.C., serving as deputy director of NDRC's Division A (Armor), Caltech's Charles Lauritsen had done early work on proximity fuzes, devices that detonated an artillery shell or a rocket within a specified distance of a target such as an aircraft or ship. While an explosion upon impact might cause considerable damage (like a single bullet to the human body), an explosion close to an aircraft, for example, would scatter shrapnel (such as a shotgun blast to the human body), resulting in substantially greater damage over a much wider area.

Although an explosive device armed with a proximity fuze appeared the perfect means of attacking a fast-moving target, a Gordian knot of technical problems had to be addressed before the concept became reality: how could a weapon be fired from a moving platform (such as a ship or plane) at a moving target (another ship or plane), detect the target at the right instant, and then explode within effective range—at the time, approximately seventy yards from the target for a five-inch projectile?[11] The technological complications of building such a device went beyond sensing a target. If launched on artillery, a fuze had to withstand acceleration equal to 20,000 times the force of gravity and the centrifugal force generated by rotating 500 times per second, this in an era of vacuum and soldered wires. And it all had to occupy a space roughly the size of a pint milk bottle.[12] Rocket projectiles would produce less physical stresses on the device, but would be no less demanding in their speed; the time period for a fuze to sense it was near its target and send an electrical signal to a detonator was mind-numbingly brief.

Pre-war research on infrared heat-sensing fuzes triggered by proximity to an airplane engine proved unsatisfactory, and radio-based designs were too large and not rugged enough; acoustic designs failed as well. As war loomed, the Bureau of Ordnance decreed development of a proximity fuze a priority. The conceptual

[11] Captain Linwood S. Howeth, USN (Retired), *History of Communications-Electronics in the United States Navy* (Washington, D.C.: Bureau of Ships and Office of Naval History, 1963), 495.
[12] *History of Communications-Electronics*, 497.

Research and testing by institute technologists resulted in more than 50 fuzes for the rockets and other weapons developed on campus, in the desert at NOTS, and at Morris Dam.



breakthrough came when designers chose to use the firing forces themselves to arm the weapon by creating a battery whose electrolyte was released from a glass ampule by the shock of firing and spread by centrifugal forces, activating the fuze.

By January 1943, the fuzes were in use in anti-aircraft artillery in the Pacific, where they vastly improved naval defenses against planes, including kamikaze attacks. Near the end of the war, fuzes were being manufactured at a rate of 40,000 per day and were used widely in both the European and Pacific theaters.[13]

Recognizing their importance, Caltech had established a special group in 1942 that not only developed them, but in emergencies took on production. It was

[13] *History of Communications-Electronics*, 499.

headed by Dr. Robert B. King, a Pasadena native and an astronomer at the Mount Wilson Observatory in the San Gabriel Mountains above Pasadena before the war. His group developed fuzes for all the Caltech weapons programs, designing and testing more than 50 fuzes for various ordnance, including the Mousetrap-launched anti-submarine rocket and the barrage rocket. For his leadership of and personal contributions, King would receive the Presidential Certificate of Merit.[14]

Lewis L. Strauss, personal secretary to several presidents, put the role of these fuzes in perspective:

> One of the most original and effective military developments in World War II was the proximity, or 'VT,' fuze. It was of incalculable value to both the Army and Navy, and it helped save London from obliteration. While no one invention won the war, the proximity fuze must be listed among the very small group of developments, such as radar, upon which victory very largely depended.[15]

Mark 13 re-design

The Morris Dam facility was valuable for fuze testing and general ordnance development because it was fairly remote, half a dozen miles from the city of Azusa, with only low-key activity such as cattle grazing nearby. A Caltech team arrived in early 1943 to work the Mark 13 torpedo problem. One member was James H. Jennison, a Caltech civil engineering graduate whose initial employment was building bridges for the state of California. In the evenings, he returned to the institute to teach a class on applied mechanics and materials strength. Through associates, he learned of and volunteered to participate in a secret project one of his colleagues was working on. After an interview, Jennison requested and received a leave of absence from the state bridge department (the only leave granted to a civilian) to contribute to Caltech's portion of the war effort. He was sent to Morris Dam to assist in fabricating test facilities there, including a device called a fixed-angle launcher. The purpose was to test the faulty Mark 13 torpedo and develop appropriate remedies.

In a 1975 interview, Jennison explained that despite altitude and speed restrictions

[14] K.H. Olsen, W. Whaling, and G.D. Bell, "Obituary, Robert Burnett King, 1908–1995," *Bulletin of the American Astronomical Society*, Vol. 28, No. 4, 1453-1454.
[15] Admiral Lewis L. Strauss, quoted in: Ralph B. Baldwin, *The Deadly Fuze: The Secret Weapon of World War II* (San Rafael, California: Presidio Press, 1980), 4.

> ... the torpedo had really not been designed for the forces it had to sustain when it entered the water. Sometimes it did break in two... The tail of the torpedo was particularly vulnerable and commonly when the tail of the torpedo hit the water the elevators and rudders would be bent, the control mechanisms would be damaged and the torpedo would not control properly after that. Sometimes the torpedo broached, that is, it came out of the water and bounced around because it was somewhat unstable at the time of water entry.[16]

Navy directions on the project were specific: improve the Mark 13 so it could be dropped from an altitude of 800 feet by a plane flying at 350 knots, with a high angle of descent to make a difficult target for shipboard anti-aircraft gunners, thus obviating the Midway pilots' requirement to fly low to release their ordnance.

The Caltech team built the fixed-angle launcher against the steep side of the reservoir peninsula. Resembling a ski jump, the launcher was a 300-foot tube down which unarmed Mark 13s could be propelled at varying speeds to enter the water at a nineteen-degree angle, simulating launch from an aircraft. Afterward, torpedoes could be recovered from the reservoir and studied to determine what had happened in "flight," on impact, and underwater.[17] As noted above, water impact often crippled the torpedo. The scientists made a number of design adjustments, "but the major change was the shroud-ring welded onto the tail fins which stiffened them, strengthened them, and at the same time provided a control surface which stabilized the torpedo during this critical water entry period."[18]

With many small shops in the Pasadena area manufacturing the required repair hardware, Caltech personnel would meet aircraft carriers pulling into San Diego, remove the tails from their torpedoes, truck them to the institute's campus, weld on shroud rings provided by commercial suppliers, and return them to San Diego before the carrier sailed. Jennison noted that while the Caltech work with rockets was publicized, the torpedo work (even the word "torpedo") was classified.

The result of the torpedo improvement efforts, states the Center's fifty-year history, was substantial: "The ring-tailed torpedo first saw operational use on 4 August 1944, and it paid off for the Fleet in the tremendous victories won by Navy aviators at the battle of Leyte Gulf in October 1944. Sixty Japanese ships were sunk at a cost of seven U.S. vessels."[19]

---

[16] James H. Jennison, Naval Weapons Center interview conducted by J.D. Gerrard-Gough, October 23, 1975, 2.
[17] NOSC, *Fifty Years of Research and Development on Point Loma*, 15.
[18] Jennison interview, 2-3.
[19] *Fifty Years*, 16.

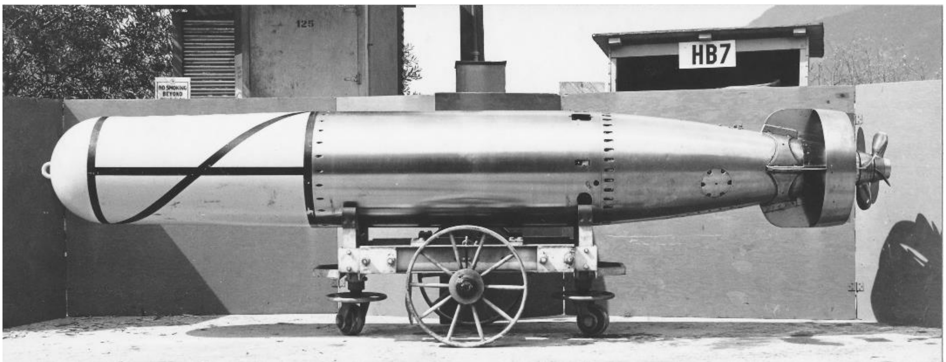
Mousetrap-launched anti-submarine rocket

While the torpedo work would ultimately occupy a significant percentage of the personnel resources in Pasadena, the Caltech war effort was mainly directed at the development, testing, and fielding of rockets.

In a speech two decades later, Dr. Charles Lauritsen recounted:

> In the spring of '42, this country's biggest menace was clearly the submarine. We were in the war by that time. The German submarines were roaming up and down… mainly along the Atlantic seacoast and in the Caribbean and were sinking right and left, anything they saw…[20]

At the time, Dr. Lauritsen had returned recently from his work with NDRC to Caltech's Kellogg Lab, where he had taught physics classes and conducted research in peacetime. The lab was now dedicated to weapons research and development. In his speech, he recounted how the Navy had "requisitioned" a number of private boats and yachts on the Atlantic Coast, adding sonar gear to aid in the search for U- boats, but acknowledging they were unarmed. Caltech personnel had heard about the British weapon called Hedgehog, something like an



After erecting a test fixture on a steep hillside at Morris Dam titled the Fixed-Angle Launcher, Caltech engineers countered the water-impact vulnerability of the Mark 13 torpedo by welding a shroud ring onto the tail fins. Their efforts resulted in a powerful air-dropped weapon that decimated Japanese naval forces in Leyte Gulf.

[20] Dr. Charles Lauritsen speech at dedication of the Weapons Exhibit Center at the Naval Ordnance Test Station, China Lake, November 4, 1964, cited in *Sailors*, 131.

inverted mortar, employed successfully on some U.S. destroyers. Realizing the recoil of such a weapon would severely damage, if not sink, a small wooden yacht, Caltech designed a launcher nicknamed "Mousetrap" operating on Hedgehog principles. The launcher weapon was a 7.2-inch-diameter anti-submarine rocket.

After successful demonstration testing in Key West, Caltech was tasked with providing one boat's worth of equipment and ammunition a day, beginning thirty days after start-up. Ordered were "367 launchers and 45,424 ASRs. This was the nation's first substantial requirement for tactical rockets."[21]

This also represented early cooperative projects between the Pasadena and San Diego Navy R&D teams. For example, the first test firings of the Caltech Mousetrap ASRs in water were done in San Diego in the spring of 1942, by some combination of the Radio and Sound Lab and the UC Division of War Research. UCDWR developed the ABN7A fuze for Mousetrap-fired weapons, one of many tested at Caltech's Morris Dam facility by Robert King's team there.[22] During testing of NRSL's Sono-Optical Recorder, which was developed to allow "scoring" the success of Mousetrap-launched ASRs, Caltech provided NRSL with sub-caliber training projectiles, which they nicknamed "Minnie Mouse."

Both NRSL and UCDWR reports also mention participation in Mousetrap-launched weapon testing in Key West. The latter record Dr. Harnwell, the second director of UCDWR, conferring several times with Caltech personnel on ordnance training issues at Key West in the summer and fall of 1943. Caltech personnel traveled to the West Coast Sound School in San Diego to discuss the Mousetrap program with UCDWR officials and their possible participation in this work.[23]

Lauritsen himself expressed substantial doubts that the launchers on the East Coast yachts ever sank any submarines, but considered it good for morale and thought perhaps it "bothered the submarines a little bit."

---

[21] *Sailors*, 132.

[22] UCDWR Bi-Weekly Report of December 13-26, 1942, 6: "The results appeared to be satisfactory; they will be reported by CIT [California Institute of Technology]." According to the January 10-23, 1943 report, fuzes were being considered for the Mark

[23] UCDWR Bi-Weekly Report of November 28-December 11, 1943, 1.

Dr. Charles C. Lauritsen

Contrary to those expectations, however, was the fact the rocket launchers made their way by the spring of 1943 to the Pacific, where they were placed on ships as large as destroyer escorts. Generally fired first in the suspected presence of a submarine, the rockets reportedly ruptured the pressure hulls of some submarines, forcing them to surface, where they were much more vulnerable to attack. In the instances when the submarine did not surface, once the rockets produced reasonable evidence of a sub, such as an oil slick, the surface ships' primary anti-submarine weapons, depth charges, were brought into play.

"Retrorocket" testing

In 1942 and 1943, the Caltech team tested rocket propellant and designs at Goldstone Dry Lake in the Mojave Desert.[24] There, one of the more unusual anti-submarine weapons was tested. A Navy PBY Catalina "Flying Boat" was equipped with a device called the Magnetic Anti-submarine Detector (MAD), which signaled an aircraft pilot a submarine was immediately below. An array of

[24] Now the site of NASA's Deep Space Communications Complex, an array of radio telescopes run for the Jet Propulsion Laboratory.

the 7.2-inch anti-submarine rockets was mounted under the Catalina's wings, but, unlike the usual configuration when fired from a Mousetrap launcher, mounted to fire *backward*, behind the plane. With the plane cruising at the appropriate speed, the ASRs, fired backward, would drop back on the spot where the MAD had detected a submarine. Testing this on a dry lakebed was accomplished by stringing a coil of insulated wire between two telephone poles and running a current through the wire, which created a magnetic field similar to that of a submarine.

On July 3, 1942, a PBY cruising over Goldstone Lake fired its retrorockets at the desert floor, the first time a rocket had been launched from an American aircraft.[25] Appropriate testing in the desert demonstrated that launching a small set of the explosives in a line provided a high probability of a hit.[26] With the testing completed, the retrorockets were used successfully in combination with ships and other airborne weapons to detect and destroy submarines later in the war; their first confirmed kill was the German *U-761* near Gibraltar on February 24, 1944.[27]

The weapon was an important first for the California Institute of Technology:

> It [ASR fired by Mousetrap launcher] goes down in history as the first CalTech rocket to be fired against the enemy. And since the CalTech program became the beginning of the Navy's modern rocket program, the antisubmarine rockets launched from the Mousetrap launchers were the first Navy rockets of the new era to see tactical use.[28]

It was not, however, the first successful Caltech rocket product.

As noted in Chapter 1, Caltech's Dr. Richard Tolman had been requested by Vannevar Bush to come to Washington to head NDRC's Division A. He had asked his institute colleague Charles Lauritsen to join him as his deputy. Lauritsen had spent a number of months working multiple facets of munitions development.

On April 1, 1941, Lauritsen wrote Tolman, advocating strongly for an aircraft and anti-aircraft rocket program, pushing for two projects—a five-inch-diameter aircraft rocket and a 3-1/4-inch-diameter anti-aircraft rocket, both with proximity fuzes. He suggested Caltech was in a "particularly favorable position" to pursue the five-inch rocket. With the news a test range near Barstow (four hours' drive

---

[25] "Caltech's Other Rocket Project," 7.
[26] James Phinney Baxter III, *Scientists Against Time* (Boston: Little, Brown and Company, 1946), 205-6.
[27] Roy A. Grossnick, *United States Naval Aviation, 1910–1995, Part 5, World War II 1940-1945* (Washington, D. C.: Naval Historical Center, Department of the Navy, 1997), 151.
[28] *Sailors*, 33.

from Pasadena) might be available, Tolman wrote Bush on August 9, proposing a $200,000 contract to Caltech to develop a high-altitude anti-aircraft rocket.

Lauritsen's pushing the rocket development concept resulted in a request from the Army Chief of Coast Artillery for a rocket that would allow gunners to practice on a more realistic target, and the National Bureau of Standards immediately set to work on it, with Caltech personnel, including Lauritsen, involved. "Thus, the early target-rocket work at the National Bureau of Standards was essentially the beginning of the CalTech rocket work."[29] By the fall of 1941, Lauritsen and Dr. William A. Fowler, also of Caltech and a key project engineer, had developed a prototype rocket. After testing attended by the Coast Artillery general, who was delighted with the results, the subsequent production program was well underway by the time of Pearl Harbor. Also, because that was the underlying reason for the tests, it provided the impetus for the general to offer use of an area near Goldstone Lake, in a corner of the base at Camp Irwin, to test fire target rockets.[30]

With the target-rocket work moving forward in Pasadena and the California desert, Vannevar Bush established two major contracts for rocket development—one with George Washington University (working with the Naval Ordnance Laboratory) and the other with California Institute of Technology.[31] Lauritsen, who had returned from his trip to England to view British rocket developments in late summer-early autumn of 1941, had been directing the Caltech group in developing rockets while awaiting the legal documentation to formalize the effort. Re-establishing himself in Caltech's Kellogg Radiation Laboratory, Lauritsen had assembled a team of physicists and chemical engineers to design a high-altitude anti-aircraft rocket. The team included his son, Dr. Thomas Lauritsen.

Propellant differences become mean-spirited

The two rocket development organizations almost immediately diverged on a principal facet of the weapon—its propellant. Indian Head favored a wet extruded product, believing it was the best hope for an early supply of propellant to begin

---

[29] *Sailors*, 113.
[30] *Sailors*, 121.
[31] The Caltech contract was actually signed February 19, 1942, but, in a parallel to work assignments prior to formal contracts characterizing the establishment of UCDWR and CUDWR (see Chapter 1), the contract was made retroactive to September 1941.

testing rockets. The elder Lauritsen, undoubtedly influenced by the work he'd seen in England, favored a dry extrusion method, realizing there were more technical problems to be solved, but doubting wet extrusion could provide large enough diameter strands of propellant to be effective.

Unfortunately, key officials at Indian Head effectively blocked the Caltech effort to procure sheets of ballistite for dry extrusion. Frustrated at that, Charles Lauritsen went to his former Caltech and NDRC Division A colleague in Washington for assistance. Whatever Dr. Tolman said or did, on February 7, 1942, 2,000 pounds of sheet powder ballistite arrived at the Kellogg Laboratory, the first installment of many that kept the Caltech team in raw material for extruding their projectile grains.[32]

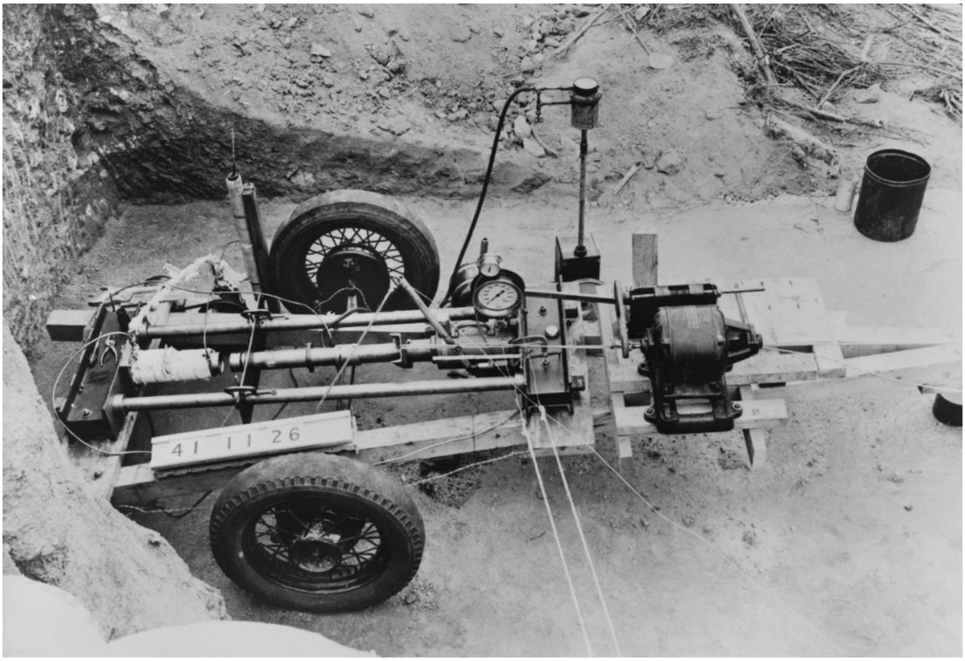
In short order, Thomas Lauritsen assembled an extrusion press using a vacuum technique that could make larger grains of ballistite, at first 15/16 inch in diameter and eventually reaching diameters up to 4.5 inches. To avoid possible mishap, the team mounted their press on wheels and towed it beyond Pasadena residential neighborhoods to a remote area called Eaton Canyon at the base of the San Gabriel Mountains, where they initially produced ballistite grains for several months, running the press while sheltering behind a sandbag barrier.[33]

Finding the ballistite worked successfully in their rockets, the Caltech team leased a tract of five acres at Eaton Canyon (ultimately growing to 150 acres) from the city of Pasadena to produce their inherently dangerous propellant. Over the next several years, the team produced nearly five million pounds of propellant there. (Originally, propellant production there was to be limited to experimental and early development rockets, with manufacturing facilities set up in some appropriate location for actual weapon production. In actuality, Caltech frequently received and responded to emergency requests for the propellant grains.)

With the propellant issue generally settled, Caltech began producing rockets for combat use, the first of which was the 7.2-inch rocket coupled with the Mousetrap launcher, discussed above. As that effort proceeded, frequent testing was done at the range near Barstow, to which interested military personnel were often invited. A chance conversation between Charles Lauritsen and an interested attendee at one of those tests initiated the next major Caltech rocket program.

---

[32] *Sailors*, 125-6.
[33] *Sailors*, 118-119.



Charles Lauritsen favored dry extrusion of propellant grains for rockets. His son, Dr. Thomas Lauritsen, assembled an extrusion press, mounted on wheels so it could be towed to a remote location called Eaton Canyon. Before the end of the war, more than five million pounds of propellant grains would be extruded there.

Vice Admiral Wilson Brown, just selected as Commander, Pacific Amphibious Forces, attended a test demo in mid-June 1942. Lauritsen, always seeking opportunities for demonstrating the value of rockets in battle, asked him if they might be useful for defensive purposes. The three-star naval officer vocally advised there was no need for defensive measures since he intended to be on the offensive. He followed that up, however, by providing Lauritsen a golden opportunity when he explained the process of troops going ashore on enemy-held territory. The heavy shore bombardment from Navy battleships to "soften up" defenses had to cease, he lamented, as landing craft began motoring to the beach. The lull provided the enemy time to re-form defensive positions before the landing craft hit the sand. A weapon with a range of 1,000 to 1,200 yards that could be employed when the sixteen-inch guns were silenced would be of substantial value.

Lauritsen initiated "one of the fastest responses in history of a technical program to new battle requirements,"[34] pushing his rocket designers to give him a weapon suited to the stated requirements. In less than two weeks, those designers had combined the features of the ASR weapon and earlier rockets into barrage rockets and were testing them. In another two weeks a launcher was completed. Fuzing as usual took longer, but within two months of the Vice Admiral Brown-Lauritsen discussion, a demonstration of the resulting rocket was held in Maryland. Carrying a twenty-pound charge, it was launched by a Mousetrap Mark 3 engine, and while in flight stabilized by an annular fin. Immediately following that demonstration, the Bureau of Ordnance demanded operational weapon systems—fifty launchers and 3,000 each rockets and fuzes, in thirty days.

Caltech's response was to charge their weapon developers with production as well. Assigning as much production to contractors as possible, technical personnel inspected contractors' work and office personnel staffed the institute's own assembly lines. By October 10, four months after the chance conversation between Lauritsen and the vice admiral, the last rockets were completed and delivered.

Used initially in the landing at Casablanca on November 8, 1942, (coincidentally the birth date of NOTS the following year), the rocket was a tactical success, filling, as requested, the gap between the time battleship guns ceased shelling shoreline defenses and men waded ashore. More than 1,600,000 barrage rockets were manufactured during the war, produced initially only by Caltech personnel and their immediate contractors, but then commercially.

The rockets performed so reliably that the weapon was nicknamed "Old Faithful." A barrage of 4.5s launched moments before invasion was so destructive and disorienting to defenders that in their Pacific debut, on the island of New Britain in December 1943, Marines in the first wave of attack met little resistance. After their introduction, the Navy employed the rockets in every subsequent amphibious assault, both in Europe and the Pacific.[35]

The desert

As research progressed on every component of military rockets, the Caltech

---

[34] *Sailors*, 138

[35] "Caltech's Other Rocket Project," 6.

team discussed the need for a safer place to test their propellant products. Eaton Canyon was nearby but insufficient for in-flight tests. Moreover, the chemical and mechanical work grew hazardous. In the spring of 1942, two workmen, Raymond Robey and Carl B. Sanborn, were burned to death in separate accidents (Robey in the Kellogg Laboratory, Sanborn in Eaton Canyon) while working with ballistite grains. Clearly, producing large amounts of rocket propellant, not to mention testing rockets, wasn't going to continue in the leafy city of Pasadena for long.[36]

As discussed above, Caltech used the Army Air Corps anti-aircraft range near Barstow for testing the target rockets and the 7.2-inch anti-submarine rockets to be fired by the Mousetrap launchers. Soon, Marines were training in the use of those rockets and Mousetrap-launched ASR rockets at Goldstone Lake as well, and the success of the Caltech rocket programs overwhelmed available space.

An early 1943 effort, supported by the Commandant of the Marine Corps, was to establish a rocket firing range at the sprawling Marine base at Camp Pendleton, located about midway between Los Angeles and San Diego, and a fairly easy drive south from Pasadena. Unfortunately, problems surfaced there almost immediately when the range officer tried to fit the requirement for a 12,000-yard range: at the south end of the base, there were a lot of people living, working, and playing close by; in the north, the land was cut up with canyons. Despite Pendleton's huge acreage, its closest options to the requirement were a 5,000-yard range over land and 10,000 yards over the ocean. Thus, although substantial testing of fuzes was done at the base, it wasn't the answer Caltech engineers were seeking.

Another range was offered at the Salton Sea, but it provided little support for a large test area. It was used primarily for training pilots in the use of the Magnetic Anti-submarine Detector and the test firing of retrorockets.

By the summer of 1943, it was clear the problem of finding a useable test range was a joint Caltech-Navy one, and they had to solve it jointly. The institute already had some fair successes to its credit: the target rocket was providing a valuable resource for training applications; the ASRs fired from Mousetrap launchers demonstrated rockets were a valuable addition to shipboard weapons; the 4.5-inch barrage rocket had demonstrably proven the value of such weapons to amphibious operations.[37] Eager to move ahead with what he considered critical to the Navy's weapon inventory, Lauritsen hosted a meeting at Caltech of officials

---

[36] *Sailors*, 126-28.
[37] *Sailors*, 140.

from the Office of the Commander in Chief (COMINCH) and from the Ordnance and Aeronautics bureaus. Encouraged by the interest and enthusiasm of the uniformed attendees, he proposed an accelerated program at Caltech for the development and production of rockets, and sought a naval officer with authority to approve decisions related to that development.

On June 7, COMINCH issued a memorandum calling for a major aircraft rocket program and directing the two bureaus to collaborate with Caltech to develop and test rockets. The Commander, Fleet Air, West Coast, was ordered to support that by providing aircraft and personnel for the effort, and coordination with the National Defense Research Committee was directed.

What the memo did *not* order (or authorize) was establishment of a rocket test station or a weapons R&D laboratory. Nevertheless, that memo would be viewed very shortly as the authority for establishing just such a station/laboratory.[38]

Sherman Burroughs

Coincident with the generally unsuccessful test range search on the West Coast, across the country Commander Sherman Burroughs had arrived in March 1943 at the Navy's Bureau of Ordnance for his new assignment as aviation assistant to the director of research and development. One of the pioneers of naval aviation, he was also a highly decorated combat pilot who, perhaps chafing at the idea of flying a desk in Washington in the midst of a war, also realized his new position provided him some strong leverage to assist his fellow pilots with what they needed most—improved aviation ordnance. With a colleague, he had visited the Army Air Corps base at Eglin Field in Florida, after which the two concluded the Navy required a fairly large area to test that ordnance, whatever it might be.

One of his next visits was to Pasadena to meet Charles Lauritsen, who took him out to Goldstone Lake to see some rocket testing. Caltech developers had been using the site on the Army's sprawling Camp Irwin for weapons tests since the fall of 1941. Clearly the desert area around the lake provided some of the characteristics Burroughs envisioned as requirements for the test range, but its shortcomings were substantial, not the least of which was the long drive over back

---

[38] *Sailors*, 149.

roads from Pasadena. (The classified nature of their work, plus the highly explosive and as yet unpredictable performance of their rockets, forced them off main highways for security and safety reasons. Once on site, they had to negotiate desert roads, or none, while searching for an appropriate "flat" place to fire their weapons.) There were no facilities of any kind at these sites: no launchers, no emergency equipment in case of fire or injury (both reasonably possible if not probable), no place to refuel the test aircraft.

During the visit, Lauritsen offered the naval aviator the opportunity to get in an aircraft and fire some rockets. In an interview several decades later,[39] Burroughs made it clear he was substantially impressed, both with the rockets and with the Caltech group developing them. According to the interview, he proposed to Lauritsen the need for an "aviation weapons field… accent on testing," and Lauritsen "jumped right in and said it was a wonderful idea." The latter recognized that Burroughs' plan was completely consistent with his own desire for a rocket test range, especially since air-launched rockets were almost certain to be a major component of the Caltech effort. As the authors of the second volume of the China Lake history saw it, "When Burroughs and Lauritsen looked at the needs of their separate programs, they saw the advantages of combining the aviation ordnance requirements for a proving ground with the CalTech need for space for rocket testing and training."[40]

Lauritsen and Burroughs team

Burroughs returned to Washington and developed a proposal he presented to Rear Admiral William H. Blandy, the chief of the Bureau of Ordnance. Although testing areas existed on the East Coast, Burroughs had in mind something larger and more comprehensive. He later recalled, "We needed an equivalent of a Peenemunde, this German place where you could build, design, develop, etc. weapons in secret so that nobody knows what the hell you're doing..." [41]

---

[39] Burroughs interview, 18.

[40] J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 2: The Grand Experiment at Inyokern* (Washington, D.C.: Naval History Division, 1978), 7.

[41] Sherman E. Burroughs interview by Albert B. Christman, April 1966, 9. Peenemunde was the German rocket laboratory, production facility, and launch area on the North Sea, site of V-1 and V-2 development. Its chief scientists included Wernher von Braun.

With a distinct sense of trust gained in their short time together at Caltech and in the desert, Burroughs worked the chain of command in an appropriate fashion. Lauritsen was busy directing the newly approved rocket development program, which scored major successes around the time of Burroughs' visit— the July 14, 1943 first air launch of forward-fired rockets (British rounds, but significant to the Caltech program because they were demonstrative of the capability), followed five weeks later with the first launch of Caltech-developed forward-fired rockets.[42]

Almost coincident with that first test launch was the immediate jump into production by Caltech personnel. COMINCH directed equipping 6,000 aircraft with rockets. Although seventy-five percent of those were planned for the Pacific, the majority of the rockets being produced in Pasadena in the fall of 1943 were shipped to the East Coast for use against the alarming U-boat threat.[43]

While heavily involved with managing his new and quickly expanding rocket program, Lauritsen nevertheless managed (one might almost say was required) to find time to study maps carefully and fly reconnaissance missions in a one-engine Beechcraft piloted by Navy Commander Jack Renard, searching the open spaces beyond the San Gabriel Mountains for a suitable location to test rockets. In their relatively casual search for a reasonable location, overflying the substantially restricted Army Air Force desert bombing range, they were stunned to find "a large, well-developed, hard-topped landing strip empty and ready for use in a vast desert area where there were only a few scattered ranches and mines and a cluster of a half dozen buildings known as the village of Inyokern."[44]

A long flat valley ran north from Inyokern, separating Sequoia National Forest and Death Valley. Looking for a place to start rocket testing almost immediately, they had found one.

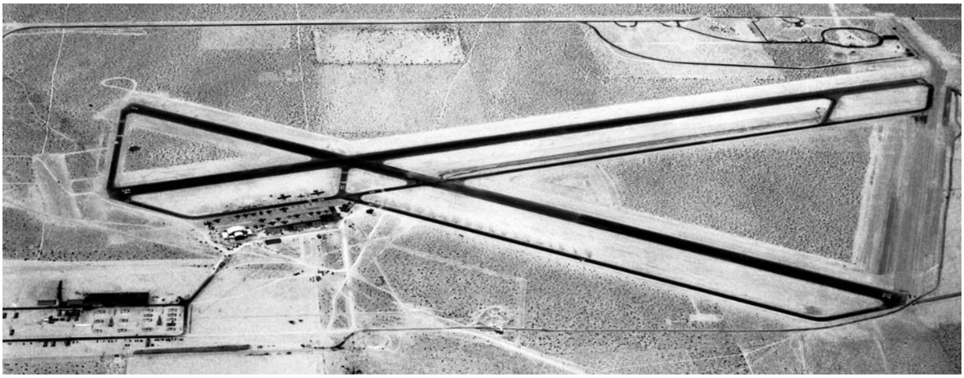
(Renard, by the way, was substantially more than a Navy pilot. Lauritsen had sought, as early as the meeting with Navy officials in about May 1943, "an officer within reasonable distance of CalTech who could act essentially as a rocket czar

[42] *Sailors*, 150. Actually the Army launched a 4.5-inch forward-fired rocket a year earlier at Aberdeen Proving Ground, but West Coast Navy pilots (and the author of the China Lake history Volume 1) glossed over that fact, stating, "The distinction was that the British rockets were the first air firings in a distinctly Navy approach to aircraft rocketry." Understand. Distinctly.

[43] Memorandum from Office of the Chief of Naval Operations to Commander in Chief, U.S. Fleet, subject: Distribution of High Velocity Rockets, November 5, 1943.

[44] *Sailors*, 168-9.

in making authorizations without having to obtain prior approvals of the Bureaus concerned."[45] He pushed for that officer again after the June 7 memo of COMINCH, considering that as a primary solution to the problem he'd experienced earlier of political in-fighting between the bureaus that retarded, or precluded, progress. In the latter instance, it is fairly reasonable to suppose he was thinking of Commander Renard, who in fact was the officer selected for the post.)



Key to the early success of the Caltech and Navy weapons development effort was the discovery of a perfectly suitable airfield in the middle of the Mojave Desert. The joint efforts of Dr. Lauritsen and Captain Burroughs secured that field for the beginnings of the Navy lab there.

The next time Sherman Burroughs traveled from Washington for a weapons test at Goldstone Lake, accompanied by BuOrd colleagues (including Captain James C. Byrnes, the bureau's administrative officer for ordnance stations), Lauritsen arranged a "detour" on their return trip to the Burbank airport. After months of discussing in vague generalities what an aviation ordnance test range might look like, seeing the Indian Wells Valley and the Inyokern landing strip was believing for them. Captain Byrnes was "immediately impressed" with the desert locale; in addition to the value of wide-open spaces with few signs of civilization and almost no people, he had another thought, based on his experience with the proximity of the Navy Proving Ground to the nation's capital:

[45] *Sailors*, 148.

> I think it's the greatest mistake, putting a laboratory where everybody in the Bureau can hop in an automobile and get over there and stick their oars into it. You ought to get your laboratory as far away as you possibly can so that people here in the Bureau will leave them alone and let them get ahead.[46]

(As we shall discuss in Chapter 11 relative to establishment of the Hawaii Laboratory, these were words that could have been taken directly from the mouth of later test station technical director Dr. William B. McLean.)

With leadership from Rear Admiral (later Admiral) Marc Mitscher, Commander, Fleet Air, West Coast, the Navy pushed the Army Air Force for title to its Mojave Desert range at Inyokern. The timing was good, as the Navy had recently established a new high-level position, Deputy Chief of Naval Operations (Air), and the first selectee for the position, Rear Admiral (later Admiral) John S. McCain, had been pushing for months for an expanded rocket program. He became a strong ally to Rear Admiral Blandy at the Bureau of Ordnance.

"Bombing range" established at China Lake

In the autumn of 1943, the Navy officially requested authorization to use what it termed the "China Lake Bombing Range," titling it for the dry lake bed where the service intended to lay out its weapons testing facility. Several weeks later, a trio of Caltech scientists drove out to the desert in a four-wheel drive weapons carrier, armed with sleeping bags, provisions, and appropriate equipment to reconnoiter, map, and photograph the area. Their immediate goal was location of an optimal venue for testing rockets, but they had a longer-term purpose as well: "It was understood by the survey team that they were looking not for just rocket-testing space but for a location for a permanent naval ordnance station where the CalTech work and techniques could be transferred at the end of the war."[47]

To provide "ground truth" whether the Indian Wells Valley was as valuable to his rocket testing as he hoped, Lauritsen had sent the three-man team—Dr. William Fowler, Dr. Ira Bowen, and Wesley Hertenstein—to investigate and

---

[46] Captain James C. Byrnes NOTS interview, May 1967, 25-26.
[47] *Sailors*, 182.

report on its utility for his desired purposes. Typical of Lauritsen, the selection had been made carefully: Fowler was only slightly less regarded in rocket development than Lauritsen himself; Bowen would be responsible for instrumentation systems to ensure desert testing was equivalent to laboratory testing; and Hertenstein had been key in developing the facilities for Eaton Canyon and Goldstone Lake, and thus critical to similar tasking if the new location proved feasible.

The trio spent the days drawing maps and photographing the area, particularly the dry bed of China Lake, and the nights in sleeping bags, essentially living out of the weapons carrier. One of their more critical tasks was selecting a specific locale where huge acreages of sand and scrub provided 15,000 yards of downrange space for live and inert rocket firing. At a point common to two side-by-side ranges, they noted the probable location of "No. 1 Launcher." Their positive response to Lauritsen was transmitted immediately to Office of Scientific Research and Development sponsors, nearly coincident with the Navy decision to equip 6,000 of their aircraft with rockets. Thus, Navy operational and testing requirements were on the verge of coming together in the Mojave Desert.

Although the surveying scientists might have believed at the time in a permanent rocket-testing base, in most of the important circles there was no clear vision of what the new facility should be or of its future when the war ended. The venue, should it prove available from its Army "owners," had possibilities for a variety of uses, both short- and long-term. Of the BuOrd officers involved in the Inyokern fly-over, Captain Byrnes was the one who focused on the future, seeing a permanent R&D facility for the postwar period, or "for the next war." Of the duo who would be the principal actors in this drama, Commander Burroughs desired a facility to develop effective aviation ordnance for his fellow pilots as quickly as possible, but "from the start Burroughs' objective was to make a complete and permanent aviation ordnance facility on the desert..."[48] Lauritsen wanted to be able to fire rockets safely. And immediately. The reporting senior for Burroughs and Byrnes at BuOrd, Rear Admiral Blandy, had taken the bureau from a relatively relaxed, peace-time existence to an all-out world war, in which he was about to go to sea and engage in combat. A man given to considering the long-term as important as the immediate crisis, he visualized the momentum that was provided by the war as an important stimulus to projecting valuable Navy research and development into the future period of peace all hoped would come sooner rather than later.

---

[48] *Sailors*, 201.

His response to the concept Burroughs presented

> was to switch the long-term emphasis, although not the immediate priority, from the wartime needs that preoccupied Burroughs and Lauritsen to the broader concept of a permanent research and development center for ordnance that would serve the Navy's needs in both war and peace.[49]

After a month of deliberation, the various government agencies with claims in the matter agreed on October 24 the Navy could assume control of the desert area around the Inyokern landing field.

Construction begins at Inyokern

Four days later, the Vice Chief of Naval Operations approved the start of construction of temporary facilities at Inyokern "for the expedition of the rocket program." His approval order included construction of three Quonset huts and a mess hut, five magazines and a refrigerated ammunition storage hut, and an access road to bring in the construction materials and the crew to put them together.

On October 30, newly promoted Captain Sherman Burroughs completed and passed to his superior a detailed memo on planning for the new station, a memo which included a nomination of himself as the commanding officer and a proposed title for the base. On November 2, Rear Admiral Blandy sent a memo to the Secretary of the Navy, advocating the establishment of the desert naval base and providing a proposed title: Naval Ordnance Test Station.

During these eventful few days, one of Blandy's key advisors reviewed Captain Burroughs' memo and provided feedback, including the decision he would not be the commanding officer and the fact his suggested list of three officers to travel to Pasadena to proceed with base planning had been reduced to one, and that one was not Burroughs. Disappointed personally, Burroughs nevertheless charged ahead with his bureau assignment by developing a detailed memo "For Files" dated November 5. Among its most significant features was its clear distinction between efforts already underway to set up temporary facilities and the captain's thoughts on a permanent station. The latter included quarters not only for military personnel but also for civilian scientists and engineers.

---

[49] *The Grand Experiment*, 9.

Bureau of Ordnance officials completed required details, and on November 8, 1943, Navy Secretary Frank Knox established the U.S. Naval Ordnance Test Station, Inyokern, California.

Within a few days, perhaps as a result of his November 5 memo (although there is no written evidence that was the specific reason), Bureau of Ordnance officials reversed their decision on the new station commanding officer, and Burroughs was ordered to travel to Pasadena, as soon as he could close out his pressing business in Washington, to assist in planning early development of the new test station, which he would command.

While Burroughs was handling that pressing business so he could proceed with planning for his station dedicated to ordnance testing, a group of Caltech scientists was heading toward that station, specifically to conduct ordnance testing.

First rocket tests

Sketchy records exist suggesting the first test at the station was conducted less than three weeks before Captain Burroughs arrived, on December 3, 1943. That particular test involved air launches of 3.5-inch rockets, the ones technically termed California Institute of Technology Type High Velocity 3A12 rockets. The purpose of the testing was to study the functioning of the weapon's fuze.

To effect that, another trio of Caltech scientists, also driving a four-wheel-drive vehicle filled with sleeping bags and all the food they planned to eat during a several-day effort, arrived in front of one of the partially constructed Quonset huts at the Inyokern airfield as November was turning into December. Depositing their sleeping bags inside, they headed out to the desert floor to lay out the test site on the live-firing range their associates had mapped and photographed six weeks earlier. A contract crew was on hand, in response to one of the first efforts of the Eleventh Naval District Public Works Officer to prepare for initial operations of the test station. In what would have been contractual heresy years later, the Caltech team chatted with the Navy chief in charge and then directed the Navy contractors to the spot some miles away where they planned air drops of their test rockets. They explained their requirements, and the bulldozers lumbered off over the desert to scrape out the very first test range in the valley.

The scientists, whose lives for years had involved lecturing students in formal classrooms dressed in suits and ties and conducting precise experiments in well-equipped laboratories, found themselves sleeping on the floor of a Quonset hut with no windows or doors and taking turns in the starkly cold and dark desert night standing guard over the highly classified rockets that had been delivered by a truck from Eaton Canyon and stacked up on the edge of the airfield.

On the day of the test, a handful of planes arrived, the rockets were mounted, and, with no air-traffic control, no radio communication, and only limited coordination, the aircraft flew over the test range and launched their weapons. Of the forty rockets fired, the scientists were able to locate thirty-eight craters that upon examination indicated twenty-six of the rockets had detonated successfully.

The long history of weapons testing in the Indian Wells Valley had begun.

It is probable the aircraft firing those rockets belonged to Headquarters Squadron (Hedron) 14, formed in April by Lauritsen's pilot during the "discovery" of the Inyokern airfield, Commander Jack Renard. At the time, he was double-hatted as the gunnery officer for a fleet air squadron, providing air support to Caltech testing and additionally responsible for assigning officers returning from combat to appropriate duty stations. In his support of Caltech, he had trained aircrew members for the first two Navy squadrons to be deployed with air-launched rockets. When those squadrons actually deployed, all the rocket-experienced pilots were gone, leaving no qualified air support for testing needs.

In his responsibilities as assignment officer, Commander Renard was pleased to see that one officer, Lieutenant Commander Thomas F. Pollock, had shown a definite interest in rockets, so much so that while waiting for his new assignment, he had managed to get himself placed temporarily in a group conducting flight tests on Caltech retrorockets. Commander Renard made that placement more permanent by arranging his assignment as officer-in-charge of the Hedron 14 Experimental Unit, whose mission was to support Caltech rocket testing. As "the first air unit of the U.S. Navy formed exclusively for the testing of aircraft weapons and associated equipment,"[50] the squadron had one airplane, a TBF aircraft, and one mechanic. With the memo from the office of the Commander in Chief Admiral Ernest King on June 7 directing the bureaus of Aeronautics and Ordnance to support the Caltech rocket program, Hedron 14 grew quickly in aircraft and personnel to fly and maintain them. During those early months, Pollock's

[50] *Sailors,* 220.

squadron was flying at Goldstone Lake in support of rocket testing there. Now, but still in small numbers, they were supporting the first rocket launches at Inyokern.

On about December 21, 1943, an aircraft touched down at the Inyokern airfield, and the first commanding officer of the Naval Ordnance Test Station—Captain Sherman Burroughs—stepped out. The welcoming committee, if any, was not recorded, although at the time there were about four officers aboard, presumably occupying some of the five or six Quonset huts assembled at the airfield and eating at the temporary mess hall there.

As discussed in Chapter 1, the Eleventh Naval District public works officer, Captain A.K. Fogg, had been so efficient that the essential makings of a temporary station were rolling toward the Inyokern railway siding the day NOTS was established. They were essential because otherwise Burroughs had nowhere to work, nowhere to live, nowhere to eat or sleep. The nearby community of Inyokern, population 25, had nothing to which he could turn for support while awaiting military personnel to staff and construction crews to build his station. (Although, amazingly, Fogg already had a construction contract in place.) Thanks to those efforts, however, the new commanding officer was able to move immediately into one of those Quonset huts where his plane touched down, using it as both his quarters and his office.

Commanding without a staff

With little staff (his first executive officer, he said, "wasn't much help to me," and he emphasized to the Bureau of Ordnance that more than a month after his arrival he had only one yeoman for admin and clerical duties), Captain Burroughs nevertheless plunged into his assignment, fully aware of the responsibilities of his organization. In an early meeting with his ten officers, he impressed one enough with his message that the junior officer remembered it decades later:

> I think we still have a long war ahead of us… this Station is going to be an important factor in beating the Japs, and the work is going to be done mostly by civilians with you men backing them up. I don't like this situation any better than you do, but we just don't have Navy personnel to do the job—we have to use the brains of these professors to dream up solutions to our military problems. It is the job of all of us to see that these civilians get everything they need to do their jobs.[51]

[51] A.L. Pittinger letter to J.D. Gerrard-Gough, September 25, 1973.

No doubt that attitude, plus the usual philosophy of the new commanding officer that amicably working out difficulties through cooperative discussion was more effective than summarily giving orders, went a long way toward the early success of the organization. As was the case in San Diego with the Navy Radio and Sound Lab reporting to one of the Navy's bureaus (in that case the Bureau of Ships), so the NOTS commanding officer reported to the Bureau of Ordnance. Although Captain Burroughs had committed himself and his small team to supporting the California Institute of Technology professors, the actual tasking of the latter came from the National Defense Research Committee/Office of Scientific Research and Development, a case identical to that of the University of California Division of War Research co-located with NRSL on Point Loma. Burroughs recognized that his responsibilities were to ensure Dr. Lauritsen and his associates were taken care of as well as he could manage with his limited resources, and his efforts paid off:

> The day-to-day contacts between naval officers and CalTech civilians were characterized by a remarkably cooperative spirit, in contrast to the earlier history of military-scientific relationships in the United States and the problems that would arise at NOTS at the end of the war.[52]

In an interview some years later, Burroughs admitted his early thoughts, which significantly contributed to that spirit of cooperation:

> We would be a service organization. I say we, I mean the military would be a service organization to Cal Tech [sic] to expedite their rocket work. That's the concept I had when I went there and that I stayed with all the time I was there. All I was trying to do was provide them with everything that they needed and to building the Station—build a permanent facility... My own original concept was more along the lines of a test station. The laboratory came later, the thought of putting the big laboratory there.[53]

Captain Burroughs had pushed for the test station as a means of improving aviation ordnance, which was not the initial effort of the Caltech scientists, although it would be very soon. On the other hand, Lauritsen's team at Morris Dam was working feverishly on the precise area that had stimulated Burroughs in the first place, making the Mark 13 air-dropped torpedo functional. Clearly the creative energies of the military and civilian leaders were complementary.

A day or so after Burroughs arrived at the Inyokern airfield, the Hedron 14 Experimental Unit supporting Caltech's aircraft requirements for rocket testing

---

[52] *Sailors*, 201.
[53] Burroughs interview, 5.

was commissioned as Aviation Ordnance Development Unit 1, based in San Diego. As rocket testing at Goldstone Lake tapered off and more tests were moved to the new NOTS area, the unit's officer in charge offered: "When I was up there [at Inyokern] more than half the time, got more than half my people up there, and we were shooting rockets up there more than half the time, then we'd move."[54]

A relatively small staff led the wartime effort at Pasadena and Inyokern. The NOTS-Caltech leadership included (l-r) Commander J.O. Richardson, Dr. Charles C. Lauritsen, Captain Sherman E. Burroughs, Commander J.T. Hayward, Dr. William A. Fowler, and Dr. Emory L. Ellis.

[54] Thomas F. Pollack China Lake interview, April 1943, 22.

NOTS, 1943

Today, the Naval Air Warfare Center Weapons Division China Lake is 1.1 million acres of high desert, including mountains and forests. It is the Navy's largest single landholding, comprising eighty-five percent of the Navy's property dedicated to weapons development. It is essentially a small city of naval personnel, researchers, technicians, and their families.[55]

In 1943, China Lake was a rocky, forty-mile expanse of sagebrush desert a hundred and fifty miles northeast of Pasadena. Its dry weather, isolation from population centers, and potential for secure facilities (protecting civilian populations as well as preventing espionage) made China Lake an ideal place for testing rockets of all kinds and for manufacturing dangerous ordnance, propellants, and detonation devices.[56]

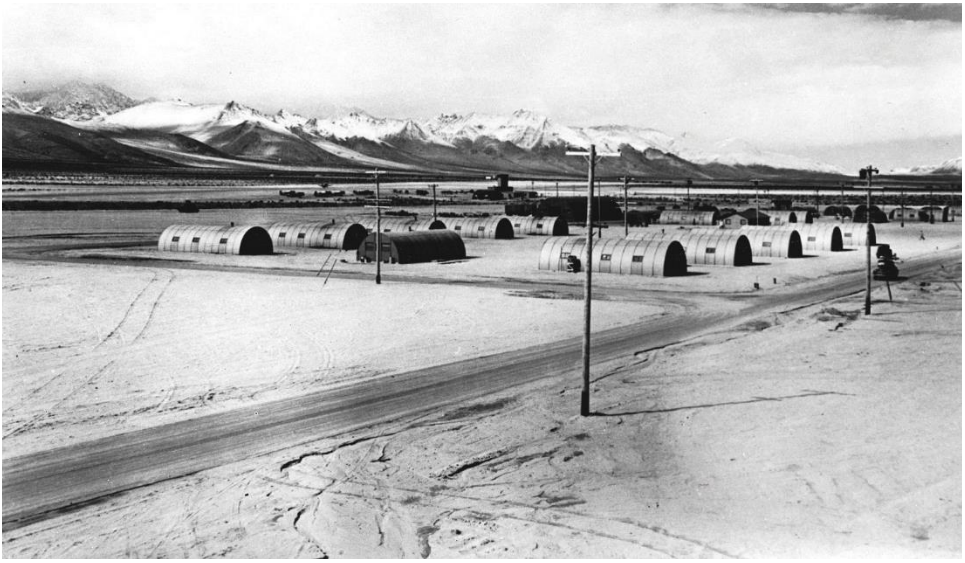
Captain Burroughs was a decorated Navy combat pilot and a competent manager, neither of which qualified him to begin even initial construction of the "small city" that would eventually blossom in the Indian Wells Valley. In the several months before he arrived, however, the Eleventh Naval District public works officer had prepared the ground work for the effort, and Burroughs only had to wait three weeks before his own permanently assigned officer in charge of construction reported for duty.

Oscar A. Sandquist arrived January 15, 1944, as the representative of the Bureau of Yards and Docks, outranking Burroughs on a technicality. (Burroughs had been promoted to captain in the fall of 1943; Sandquist was promoted to the same rank in January 1944, but the promotion was retroactive to June 1943.) More importantly, Sandquist had substantially greater experience, having served in uniform in World War I, during which he set up two naval stations back-to-back, then ran his own large construction company in private industry for a number of years before being recalled to active duty in 1940.[57]

While Burroughs managed the myriad details of establishing a new naval base

[55] Rear Admiral Mike Moran, Commander, Naval Air Warfare Center Weapons Division, "Weapons Division: Providing a Decisive and Affordable Advantage since 1943," *Naval Aviation News,* Spring 2014.
[56] "25 Years of Leadership," *China Lake Official History, 1968,* 3-8.
[57] *Sailors,* 200.

with practically no administrative or clerical support and continued to “commute” to Washington to handle Bureau of Ordnance duties, Sandquist set to work at once, recruiting nationwide for construction workers to build facilities, adminstnative



Quonset huts delivered by rail from San Diego provided the early living and working spaces for the small number of military personnel initially assigned to the new Naval Ordnance Test Station.

offices, and living quarters. Barracks, machine shops, storage buildings, fuel stations, and power lines went up. Launching platforms, firing barricades, and other experimental stations were welded, poured, and hammered together. Photographs of the Station in 1943–44 show rows of Quonset huts lined up in appropriate military regimented formation across the alkali desert.

Two days after he reported to his new post, Sandquist was in San Diego conferring with Captain Fogg about plans for base construction; during that meeting he proposed moving substantial numbers of the Quonset huts from the airfield ten miles east to the China Lake area, where major facilities for the station were under construction, to establish “a headquarters complex.” Captain Fogg called the Bureau of Ordnance and got authorization in the middle of the meeting.

Sandquist returned to the desert the next day, where in coming months there would be construction crews totaling 7,000 workers. He directed them in building a permanent mess hall and quarters for large numbers of officers, although it soon became apparent much of it was intended for civilian Caltech scientists who would arrive one day in the afternoon after a several-hour drive from Pasadena, work on the various test ranges for the next couple of days, then drive back to the city.

Construction progressed relatively smoothly until the Bureau of Yards and Docks, for whom Sandquist worked, studied the extensive building program Captain Fogg had initiated and Sandquist was now moving forward at a fairly fast pace. The initial monies, coming strangely from "Funds for Increase and Replacement of Navy Vessels," had financed much of that temporary construction of Quonset huts and bulldozer efforts on the ranges. In the Naval Appropriation Act of 1944, Congress had approved $9.5 million for more permanent construction, funds that were released February 1.

Captain Fogg had indicated months earlier to the BuOrd officers on the station planning team that their extensive plans equated in his mind to some dollar figure on the order of tens of millions. His general philosophy, fairly compatible with that of the Bureau of Yards and Docks, was that BuOrd was the customer and once someone from that organization explained the requirement appropriately, the customer would get what he wanted. Consistent with that philosophy, he proceeded with substantial laying out of construction areas and plans for those areas, which Sandquist took up and began moving forward when he arrived.

Unfortunately, the accountants of Yards and Docks carefully added numbers and came up with a total of approximately $24 million, of which only $9.5 million had been approved by Congress. The "customer," however, was not to be dissuaded from what he viewed as a critical resource for the nation, not merely for the war now raging, but for the peace time that would come.

That "customer" had changed faces but not philosophies. Rear Admiral Blandy had gone off to war, replaced by Rear Admiral George F. Hussey as the Bureau of Ordnance chief shortly before Captain Burroughs arrived at his new command. Hussey's views on the importance of that command were entirely coincident with Blandy's, and a $14 million shortfall wouldn't stand in his way.

"Neither thunderstorms nor sandstorms…"

As noted earlier, to satisfy himself he was correct, or perhaps to reap the benefits of a personal visit, Hussey made a quick trip to California in February 1944. Meteorologically speaking, it wasn't a good decision. Heavy thunderstorms inundated the Pasadena area, and the wishful thinking it would be much less wet in the desert failed to take into account the shrieking wind blowing there. The bulldozers that had scraped hard-packed earth to carve out target areas and a launcher site had left tons of loose sand and dirt to be scooped up by that wind and flung at everything in its path, which included the mess hall and the rocket launch site. The lunch sandwiches had a goodly share of that sand, and there was so much of it in the air the rocket launch was mostly unseen.

What the admiral did see and hear were the enthusiasm and confidence of Captains Burroughs and Sandquist, describing vast ranges where Navy aircraft could blast at targets with as-yet unknown weapons in absolute safety, the vision of a future ordnance research and development resource of unimaginable value, a community barely underway that would someday house hundreds of the finest scientists the nation could educate, all of them intent upon arming the Navy to the teeth. Despite the sandstorm, he'd seen exactly what he'd come to see:

> Hussey thought of the construction problems and the money problems that plagued the new organization. To go ahead with Burroughs' and Sandquist's plan would require 14 million dollars over that officially approved. To go for less would severely limit the value of the Station as a postwar ordnance center.[58]

He left with orders for the commanding officer and the officer in charge of construction to spend all the approved $9.5 million, promising to cover the shortfall. He was as good as his word. Shortly after he returned to his office, he wrote the Chief of Naval Operations, requesting half of the needed funds be added to the 1945 Public Works Appropriation Bill. He sought the other $7 million as an addition to Bureau of Ordnance funds in the 1944 Supplemental Bill.[59]

---

[58] *Sailors*, 240-241.

[59] Memorandum from Chief, Bureau of Ordnance to Chief of Naval Operations, subject: Naval Ordnance Test Station, Inyokern, California, Analysis of Requirements and Test Data, January 27, 1944.

Propellant problems

An increasingly critical problem for rocket development in the fall of 1943 was propellant manufacturing. As discussed earlier in the chapter, Caltech set up a dry-extrusion facility in remote Eaton Canyon to produce propellant. Early on, the facility was dealing with rockets numbering in the tens, essentially research projectiles to test early rocket design theories. In a time so short as to be unprecedented in the annals of weapons development, the program leaped ahead from some basic design efforts to development, testing, and, almost without pause, to production of hundreds, then thousands and multiple thousands of operational rockets. While large numbers of contractors were engaged in producing rocket motors, fuzes, and annular tail fins, initially only Caltech personnel extruded the propellant grains. It wasn't expected to be a long-term effort:

> ... it was always intended that once the designs and very special production techniques were worked out, they would be passed on to the Navy for use by large-scale production contractors. At that time CalTech would phase out of the production business and focus its scientific expertise on improved propellants and rocket designs. But demands for ballistite were overwhelming...[60]

By the fall of 1943, the canyon area had reached capacity. A new twelve-inch propellant grain press was required, and there was no space for it. Although rigorous safety measures had been adopted after the worker death there the previous spring, civilian neighborhoods were not terribly far away, and in more than one incident the scientists had to join the local fire department to put out brush fires they had inadvertently started.

Caltech personnel involved in the manufacturing process scouted several possible sites for a new extrusion facility, but then realized that the establishment of NOTS provided a distinct possibility for their expansion. A joint effort was established, with the Bureau of Ordnance turning over a large chunk of naval vessel repair funds ($1.6 million) and the Office of Scientific Research and Development kicking in $625,000 for plant equipment. BuOrd managed arrangements and safety, but requested Caltech provide a detailed plant design, which it did, and manage it when completed.[61]

Preliminary plans were drawn up for a large complex: twenty-nine permanent buildings to process propellant, another three dozen semi-permanent and

[60] *The Grand Experiment*, 137.
[61] Unpublished report "Status of the China Lake Pilot Plant, CIT," July 1944, 40.

temporary structures for administrative purposes, and a number of magazines to store explosives. A name was adopted—China Lake Pilot Plant—after Captains Burroughs and Sandquist met with the designated Caltech official in charge, Dr. Bruce H. Sage. A professor of chemical engineering at Caltech, Sage had designed and operated the extrusion press for quantity production of solid propellant at the Eaton Canyon facility. One of the hardest workers on the Caltech war-time staff ("He was putting in about a 16-hour day every day," according to Captain Burroughs in a 1966 interview), various volumes of the China Lake history titled him "builder and ruler of the China Lake Pilot Plant empire" and "boss of the pilot plants."

Bulldozers started to work on the site March 1. For about a week. Then Bureau of Ordnance officials arrived and began asking critical questions about the status of the plans (not completed, although construction had begun anyway); the nature of the intended plant product (smokeless powder or high explosive? If the latter then…); and selected location (unacceptably close by Navy regulations to station housing, specifically officers' quarters, if it was high explosive).

The BuOrd officers had more than safety in mind when they asked for a remoter plant location and more substance to the complex. They understood Caltech's leadership had provided the Navy the national lead in solid-propellant technology, and they wanted that maintained. That, and certainly safety considerations, resulted in a revised plan for nearly a hundred buildings situated four miles from the "civilized" areas of the growing NOTS complex.

Back to the drawing board, Sage oversaw development and approval of detailed new plans, jumped in a jeep and found an appropriate location and site, and construction re-commenced in May. Based on that site, and that location, and the requirements related to the environment (hot air; impervious soil; rocky, sloping terrain), the costs for the plant doubled, and doubled again. The Bureau of Ordnance was undeterred; it wanted the plant, and that was it. Five million dollars later (not counting design costs, special equipment, housing), on November 16, 1944, the China Lake Pilot Plant extruded its first grain of ballistite propellant.[62]

While the extensive effort moved forward to get the pilot plant on line, Captain Sandquist had a variety of other projects underway. As the Aviation Ordnance Development Unit moved gradually from San Diego to Inyokern, the officer in charge of construction tasked crews with improving the airstrip to

---

[62] *The Grand Experiment*, 136-144.

accommodate substantially increased flight operations. Shortly after Hedron 14 was established there, Captain Burroughs succeeded in honoring a former classmate and ordnance postgraduate, Lieutenant Commander Warren W. Harvey, by gaining approval from the Secretary of the Navy to name the airfield after him.

"Holy Moses"

As the drama was unfolding relative to the plant for rocket propellant production, the invention and improvement of the rockets themselves continued. Caltech's 3.5-inch aircraft rocket had been fairly successful, both in accuracy and velocity, but a larger explosive payload was desired. Scientists experimented with designs that would combine the high velocity of the 3.5-inch rocket with the explosive power of a 5-inch rocket that had been designed at the Naval Proving Ground at Dahlgren, Virginia. The result of those experiments was a new motor, powered by a dry-extruded propellant grain that had a cruciform cross section rather than the usual cylindrical shape.

Early versions of the new motor were launched from the ground at Goldstone Lake in December 1943. With the establishment of NOTS and the size and variety of ranges available, Aviation Ordnance Development Unit 1 pilots conducted the first air firings there of what was technically termed the High Velocity Aircraft Rocket (HVAR). On March 30, 1944, two 5-inch HVARs were fired successfully, and within six months the rocket was in production and headed to the front lines.

The second volume of the China Lake history series notes this time frame

> is all the more remarkable when one considers the scope of the entire program, embracing internal and external ballistics, safety precautions, assembly procedures, launcher installation, fuze behavior and sighting tables that were concurrently derived and delivered as a package with the operational round in July 1944."[63]

The new weapon was deployed to the Pacific and proved the most effective rocket of the war. Marine Corsairs with 5-inch HVARs under their wings sank transports at sea and smashed anti-aircraft emplacements on the ground. It was said Japanese anti-aircraft crews, spotting a Marine TBF armed with the rockets, would

---

[63] *The Grand Experiment*, 86.

hold their fire to avoid detection. The Navy was so pleased with the weapon it requested 100,000 per month.[64]

The rocket was nicknamed “Holy Moses.” Although there were several versions of the naming story, generally relating to expressions of wonder by onlookers at early tests, the one with the greatest credibility is that a member of the projectile design group uttered that exclamation as he watched the rocket blast its target. He himself said he called it that “just for the amusement of seeing if the name would catch on.”[65] When he wasn’t inventing amusing names for rockets, Conway Snyder had more serious thoughts about the efforts he and his coworkers were making:

> By sometime in 1943, Caltech’s rocket project was up to full strength, with a staff of more than 250 scientific, technical, and administrative personnel and a total employment of about 3,000. It was a group of very skilled people, highly motivated and compatible, and it was a very exciting time, in part because we were so close to the front lines. By this I mean that we would see that things that we were making were being used to great effect by the troops, sometimes within weeks or even days of the time they left our hands.[66]

Although there were reports from the front lines attesting to the success of Caltech efforts, first-hand information was always preferred. In early spring 1944, Lauritsen’s second-in-command, Dr. William Fowler, traveled 21,000 miles in sixty-six days to the combat zones, with the sole purpose of understanding how well the rockets performed and how to improve that performance.[67] While he was in the field, he not only noted successes, but commented on, and occasionally stopped to repair, weapons working less well than designed.

Destructive technologies

The 1930s were a decade of phenomenal technological achievement in Germany, most of it, unfortunately, of the destructive world-domination variety.

---

[64] “Caltech’s Other Rocket Project,” 9.
[65] Conway W. Snyder, “Caltech’s Other Rocket Project,” 10.
[66] “Caltech’s Other Rocket Project,” 7.
[67] *The Grand Experiment*, 72.

We have already discussed fulfillment of the Jules Verne fantasy with all too real *unterseeboote* and the destructive terror of V-1 and V-2 rockets. Sometime late in 1939, there were rumors of an even greater German technological breakthrough with potentially unimaginable results—the splitting of the atom. A number of important scientists in the U.S., among them Albert Einstein and Enrico Fermi, warned the nation's leaders of the dire consequences if the rumors were true.

In response, a low-key effort began to study the building block of matter and determine what, if any, terrible secrets it might be hiding. A major breakthrough by Fermi in late 1942, with the first controlled nuclear chain reaction,[68] resulted in

In a remarkably short development time (four months from first firings to fleet delivery), High Velocity Aircraft Rockets (HVARs) were provided to the Pacific Fleet air wings, where they were employed to sink transport ships at sea and destroy anti-aircraft batteries on the ground.

[68] U.S. History website at http://www.ushistory.org/us/51f.asp visited May 7, 2017.

funding to develop an atomic bomb, with the code name Manhattan Project. It also resulted in establishment of nuclear facilities in Washington state and Tennessee, and a main assembly plant in Los Alamos, New Mexico. J. Robert Oppenheimer was chosen to lead the assembly effort.

Caltech's Dr. Charles Lauritsen was one of a large number of scientists contacted about participating in the project. Although a former colleague at Caltech and an old friend of Oppenheimer's, at the time Lauritsen was heavily involved with establishing a fairly similar program for rocket development, and he declined the invitation. The two scientists went their separate ways to lead critical scientific endeavors in support of national defense.

In the fall of 1944, the rocket program was substantially successful and moving ahead on a number of important projects, while the Manhattan Project was encountering problems, including the foundational one of struggling between two major development approaches. This time Oppenheimer himself contacted Lauritsen, who responded positively since he had already sent several highly effective rockets to the front lines, had succeeded in getting the Navy to establish his rocket-testing range in the Mojave Desert, and had a new facility out in that desert to manufacture his critical component of projectile propellant.

On November 21, Dr. Frederick Hovde, chairman of NDRC Section 3, wrote Office of Scientific Research and Development chair Vannevar Bush to inform him, apparently based on an earlier discussion, he had made contact as well and "persuaded" Lauritsen to visit Los Alamos to discuss problems encountered. He made a series of proposals for Bush's approval, most important of which was:

> Dr. Lauritsen himself will spend the greater part of his time at Site Y [Los Alamos], without specific assignment. He will undertake to assist with the direction of the project, both in a technical and in an administrative way, and will in particular try to see in what ways the project to which he has until now been exclusively associated can help to solve our problems.[69]

He also advised of plans to invite the associate director of the rocket program, Dr. William Fowler, and Dr. Thomas Lauritsen for a visit to become familiar with the project and potentially assist. Understanding how this might progress, he assured his boss necessary arrangements had to be made to continue the Caltech rocket program if its major leadership was pulled away for another project.

---

[69] Dr. Frederick L. Hovde letter to Dr. Vannevar Bush, November 21, 1944.

When word spread top Caltech leaders might be assigned other work, the rocket program principal investigator, Dr. E.C. Watson, wrote two letters in quick succession to Dr. Richard Tolman, his Caltech colleague serving as head of NDRC Section A, expressing concern. Dr. Hovde wrote what he hoped was a reassuring letter back,[70] advising he understood the criticality of the program and would visit shortly after Christmas to discuss the way ahead with the appropriate people. As perhaps a pleasant but emphatic means of focusing Watson's attention on the importance of the new project, about which security concerns had dictated he be told little or nothing, Hovde advised the chairs of both the OSRD and NDRC, Dr. Tolman, and the War Department "have reached complete agreement as to necessity, priority, importance and wiseness [sic] of asking that a portion of the unique facilities and manpower at CIT under Contract OEMsr-418 be devoted to an extremely important development project."[71]

He concluded expressing confidence the project could be worked without undue impact on the rocket work. (As it turned out, that was both true and untrue.)

The letter also included a one-million-dollar sweetener of funding to get the new project rolling on Contract OEMsr-418, the rocket development contract of which Watson was principal investigator.

NOTS development expedited

The promised meeting was held on Saturday, December 30, in Pasadena, with a host of attendees from the Department of the Navy and its Bureau of Ordnance, NOTS (Commanding Officer Captain Sherman Burroughs and Experimental Officer Commander John Hayward, who actually worked for Lauritsen), and Lauritsen, Watson, Fowler, and Dr. Bruce Sage from Caltech's rocket program. Discussing the meeting in detail several weeks later,[72] Hovde as his first order of business expressed understanding of the concern about Caltech involvement in the "special War Department project" and the potential impact of that on the institute's

[70] Dr. Frederick L. Hovde letter to Dr. E.C. Watson, December 22, 1944.
[71] Hovde letter to Watson.
[72] Dr. Frederick L. Hovde letter to Dr. James B. Conant, chair of NDRC, January 16, 1945.

rocket development program. He advised the group had discussed that program in detail, and afterward there was general (but not total) agreement on a way ahead:

> ... Bureau of Ordnance will expedite in every possible way the building, staffing, and equipping of NOTS, Inyokern, and the orderly transfer of suitable rocket projects to that station as the best means of ensuring a continuance of the Navy's rocket research and development program, not only during the present war but during the coming peacetime.

There was also agreement that "... the most urgent and important aspects of the rocket development program" for the next twelve months related to improving operational use of the rockets "...can be handled more effectively by the staff and facilities at NOTS, Inyokern, as it grows into full development than by CIT."

Other circumstances cited to quell concern were that industry should be able shortly to take over rocket production, and the 320,000 pounds of rocket propellant processed *per month* would now be handled by both Eaton Canyon and the China Lake Pilot Plant.

Less than two weeks before the major meeting in Pasadena, a much larger number of people had heard about the "special War Department project," with a lot less (and, for obvious reasons to maintain secuirty, intentionally misleading) detail, via an announcement at a Caltech supervisors' meeting on December 19, 1944:

> The U.S. has no bomb larger than 2000 pounds. It is desirable to develop something comparable in size to the British 'blockbuster', especially for use from B-29's. This new project will be done in collaboration with work already started in New Mexico in connection with a proximity fuze.[73]

Despite Hovde's rational logic that Caltech's rocket work could proceed without major problems, the "special project" was in fact taking some of the program's best minds—both Lauritsens, Dr. Fowler, and Dr. Sage. On the other hand, as he stated several times, the foundational design and development work had been done, and now it was a matter mainly of improving the products operationally and reacting to any unforeseen developments. A case in point for both sides of the issue (disruption of rocket work, but at a low level) occurred in Pasadena a couple of months later:

---

[73] *Manhattan District History*, Book VIII, Volume 3, Chapter 2, Project Camel, 2.9.

> Section B was swamped, as witnessed by the fact that by the last of March 90% of the Foothill plant and personnel of Section B had been converted to Camel production. Since the priority of Project Camel greatly exceeded that of the rocket program the effect on the latter can well be imagined.[74]

As a result, Section B was reorganized on April 9 by setting up a separate group with separate facilities for rocket production: "Simultaneously an extensive modification and re-arrangement of the Foothill plant was undertaken to enable it to satisfy the requirements of Project Camel. By 1 May the plant was 95% engaged on Camel activities."[75]

Regardless of the leadership or psychological implications, Charles Lauritsen now had time to support another critical national defense project. He and several associates traveled to Los Alamos in December 1944 for briefings on the project, after which they were invited to contribute their substantial technical expertise to what would become the number one priority of almost everyone:

> Out of these conferences grew the realization that there were, in some cases, problems for which responsibility could be assigned to CIT [California Institute of Technology] in their entirety and other cases in which parallel programs with Site Y [Los Alamos] and others could be undertaken by CIT. In addition, it was obvious that CIT was in an excellent position to provide some data on the assembly, handling and ballistics of the bomb under field conditions.[76]

Lauritsen and his rocket program associates were about to plunge decisively into the development of an atomic bomb. In a 28 March 1945 memorandum to the NOTS commanding officer from the BuOrd chief, clarifying the administrative structure for control of the project-related construction at his base, Rear Admiral Hussey identified Lauritsen as "the technical director of Project 'CAMEL'..."

Two approaches considered

Oppenheimer's project at the time was considering two methods for using nuclear energy as a weapon of epic proportions. The first involved firing one mass of uranium 235 into another to create a critical mass, leading to an instantaneous explosion, the power of which no one could guess. The other approach would employ plutonium in the middle of a sphere of high explosives which would be

---

[74] "Project Camel" was the code name for Navy participation in the Manhattan Project.
[75] *Manhattan District History*, Book VIII, 2.41-2.42.
[76] *Manhattan District History*, Book VIII, Page 2.8.

detonated at various points on the periphery of the sphere. The inward explosions (hence, "implosion method") would focus their shock waves on the plutonium in the center, causing it in a similar manner to reach critical mass and explode with massive force.

The Navy's Bureau of Ordnance was heavily involved in the uranium-gun approach; Caltech was asked to support the implosion method, based on its substantial experience with two of that design's major problems. The first was "finding a reliable detonator with an action that was fast enough—a fraction of a millionth of a second."[77] The plutonium weapon as envisioned would be constructed of an unknown number of identical geometrically shaped blocks of high explosive surrounding the nuclear core. For the implosion action to work effectively, all the shock waves had to strike the core simultaneously. Thus, each block had to be detonated at the same time: "This action had to be within microseconds—as nearly simultaneous as possible."

Caltech personnel initiated their effort by testing detonator parts currently being produced in the Los Angeles area, which were of two types—spark gap and bridge wire, both of which underwent extensive examination. They designed ten models and produced thousands of devices to test reliability and measure potential for simultaneity. Component production was handled at the Office of Scientific Research and Development facility on Foothill Boulevard in Pasadena (generally termed the "Foothill Plant") and by commercial vendors. Experimental loading was done in Eaton Canyon (and later at the China Lake Pilot Plant), principally involving investigation of methods for preparation and pressing of PETN[78] and lead oxide into pellets in close proximity to the detonator's initiating parts.

Over the course of several months in early 1945, Caltech scientists were successful in designing and building the required detonators, known as "sockets."

The second problem assigned to Caltech was "infinitely more complicated and concerned the intricate high-explosive blocks themselves; their process, manufacture, and test."[79] This assignment came through the suggestion of Captain William S. Parsons, who headed the Ordnance Division at Los Alamos. Parsons was a career Navy ordnance officer who had served among other assignments at the Naval Proving Ground in Dahlgren. At that time, and on other occasions, he

[77] *The Grand Experiment*, 209.
[78] Pentaerythritol tetranitrate, a highly explosive organic compound belonging to the same chemical family as nitroglycerin.
[79] *The Grand Experiment*, 209.

had dreamed about, and lamented the lack of, a major naval ordnance development and test facility. When NOTS was first proposed, and then became a reality, he was one of its most ardent admirers and champions.

When the Los Alamos facility began to fall behind on the critical and short-fuse effort to produce the high explosives required for the implosion version of the bomb, Captain Parsons had suggested to his boss, Manhattan Project director Major General Leslie R. Groves, U.S. Army, the desirability of employing a second high-explosive plant. The recently completed China Lake Pilot Plant came immediately to mind, and he proposed to the general a potentially perfect solution to their problems: the plant, situated on the Naval Ordnance Test Station, was remote and easy to secure, and security was one of the general's biggest concerns and issues. Caltech was intimately connected to NOTS, and it was Caltech expertise that was working the problem of high-explosive design for Los Alamos. And the institute had expertise in building ordnance plants, as evidenced by the Eaton Canyon facility and the China Lake Pilot Plant.

On New Year's Day 1945, General Groves and Captain Parsons flew to Pasadena to meet with Lauritsen and Bruce Sage. The latter, with only twenty-four hours' notice from Lauritsen, already had plans to review at the meeting. He estimated plant and equipment costs at $13 million, although there were pieces of equipment and processes not only untried, but some completely unknown.

The general was pleased with the preliminary plans, and authorized Caltech to pursue the erection on Captain Burroughs' station of a huge eighty-building ordnance plant for manufacture of the non-nuclear explosive components of atom bombs. He also advised the plant had to be built and operating a hundred days after groundbreaking. Sage's response to that was not recorded.

Project CAMEL established at Caltech, NOTS

A week later, the Navy's coordinator of research and development requested, by letter to the chairman of the Office of Scientific Research and Development, the formal establishment of the project at California Institute of Technology and NOTS, under the Navy's jurisdiction,

> for experimental work at that Institute and at the Naval Ordnance Test Station, Inyokern. This project will be entitled CAMEL, and will include the design, construction, equipping, staffing

> and operation of certain facilities at NOTS, Inyokern under the jurisdiction of the Navy Department… Project CAMEL will be designated as NO-281 and will be classified Confidential.[80]

The origin of the project's code name has not been recorded, or at least the recording has not been preserved, but it covered essentially all the work envisioned at the January 1 meeting in Pasadena. The *Manhattan District History* provides a specific listing of responsibilities under the agreement, stating:

> By 8 January 1945, the program had crystallized to the point that responsibility had been designated and work was underway on: (a) Detonator development. (b) High Explosive development, including the design and construction of an explosives plant. (c) Comparison and development of firing methods and circuits. (d) Instrumentation, including electronic, mechanical, and photographic. (e) Flight tests. (f) Fusing [sic]. (g) Development and procurement of metal parts for the Camel and Los Alamos projects, together with the development of techniques and equipment for their inspection.[81]

One of the critical unknowns was whether the high-explosive blocks would be produced by casting or pressing. For a certain amount of the short construction period of the explosives plant, either could have been done, but eventually the decision had to be made. As the deadline neared for completing required facilities, Los Alamos officials were still uncertain, leaving the construction effort hanging. Lauritsen confronted them in mid-April of 1945 and insisted on an immediate decision: they went with melting and casting.

Construction contractors worked on a three-shift, no-holiday schedule on what came to be known as the Salt Wells Pilot Plant. Unique equipment had to be found and procured, or manufactured, and shipped immediately to Inyokern, all in absolute secrecy.

Ultimately the process took 115 days, but "on July 25, 1945, the first high explosives were melted, mixed, and poured at Salt Wells."[82] This was nine days after the world's first nuclear weapon "Trinity" was successfully tested in the New Mexico desert. The implosion weapon was composed of the same high-explosive components that began emerging from the Salt Wells molds the following week.

Another important Caltech contribution under Project Camel, this one also involving NOTS personnel, was training of flight crews to deliver the weapons. Originally assigned to a base in Utah, with Caltech involvement and the

---

[80] Rear Admiral J.A. Furer letter to Dr. Vannevar Bush, January 8, 1945.
[81] *Manhattan District History*, Gavin Hadden, Editor, Dept. of Energy OpenNet, 2.9-2.10.
[82] *The Grand Experiment*, 216.

participation of the naval test station the air crews were divided between Wendover, Utah, and Inyokern, with its two air fields. A group of Army Air Force personnel and their nine specially equipped B-29s reported to NOTS for training. The air crews and bombers were among the first to use Armitage Field, runways of which the Manhattan Project paid to lengthen by 1,000 feet for those planes. While they were training in weapons launch, they were also involved in aeroballistic tests to determine optimum aerodynamics of the bomb and to test fuze functioning. Hundreds of the tests were conducted at various sites; Inyokern was one of the preferred, with its precisely instrumented ranges for aerial rocket tests.

"Bricks" and "pumpkins"

Obviously for those tests and their training, the air crews needed something to drop. Consistent with the overriding security concerns, the practice weapon included a requirement for a device closely resembling a conventional (although huge and strangely shaped) bomb, and in addition titled with a non-specific name:

> In the very earliest stages of Project Camel, CIT was given complete responsibility for the development and production of the 'Pumpkin' or 'practice' bomb… Designs for an exterior casting suitable for the 'Fat Man' were provided by the Los Alamos Laboratory… The problem was the design and production or procurement of all of the components required to make a blockbuster within the limitations set up by the Los Alamos Laboratory, namely that it approximate the ballistic characteristics of the 'Fat Man' and also serve as a conventional bomb.[83]

One of the naval officers involved in the testing said later the bomb performed aerodynamically "like a streamlined brick."[84] Numerous fin designs and different means of distributing weight were evaluated in attempts to get the bomb to "fly" appropriately in a required ballistic trajectory.

While responsibility for assembly of "pumpkins" and related tasks fell to a Caltech section at NOTS, everything else associated with the scheduling of air drops, aircraft loading of practice/test weapons, and aircraft operations fell to the Experimental Officer, J.T. Hayward, who was a Navy commander (later a vice admiral) when he reported to Inyokern in August 1944. Hayward and his

---

[83] *Manhattan District History*, 2.24.
[84] F.L. Ashworth China Lake interview, April 9-10, 1969, 9.

successors (one of whom later became Chief of Naval Operations) occupied something of a "hybrid" position that would have been strange at a standard naval base, but was perhaps not so unusual at a Navy RDT&E facility:

> I was the Experimental Officer, and of course Captain Burroughs was the Captain. But I reported directly to CalTech. I worked directly for Dr. Willie Fowler and Dr. Lauritsen.... I made all the arrangements to do whatever was required in covering everything... All of the actual technical work that was done up there was done under the test request and schedules, all put out by CalTech... The Navy input of course came from the Bureau of Ordnance.[85]

In addition to atom bomb development, Caltech staffers were responsible for training air crews who would deliver the bombs from specially configured Army Air Corps B-29s. To accommodate those planes, the Manhattan Project funded a 1,000-foot extension to the Armitage Field air strip at NOTS.

Dr. Thomas Lauritsen, involved in a number of the Project Camel efforts, was responsible for one of the most critical: designing a self-destruction mechanism in the event the bomb fuzes and detonators failed to operate properly, to ensure an

[85] Captain J.T. Hayward China Lake interview, May 1966, 4.

intact bomb did not fall into the hands of the enemy: "The solution was comparatively easy, since it entailed only the inclusion of four standard service fuzes in the nose of the outer casing of the bomb and their connection with primacord to the same number of boosters in the surface of the explosive sphere."[86]

At the request of Los Alamos, procurement, crating, and shipment of materials required for overseas construction of three air-conditioned bomb assembly buildings were handled by the new NOTS officer in charge of construction, Captain L.N. Moeller. That amounted to ten carloads of material, some flown in on a special plane from the East Coast to meet the pressing deadline. To avoid surprises at the top-secret advance base where assembly would occur, Moeller supervised construction at NOTS of buildings identical to the real thing.

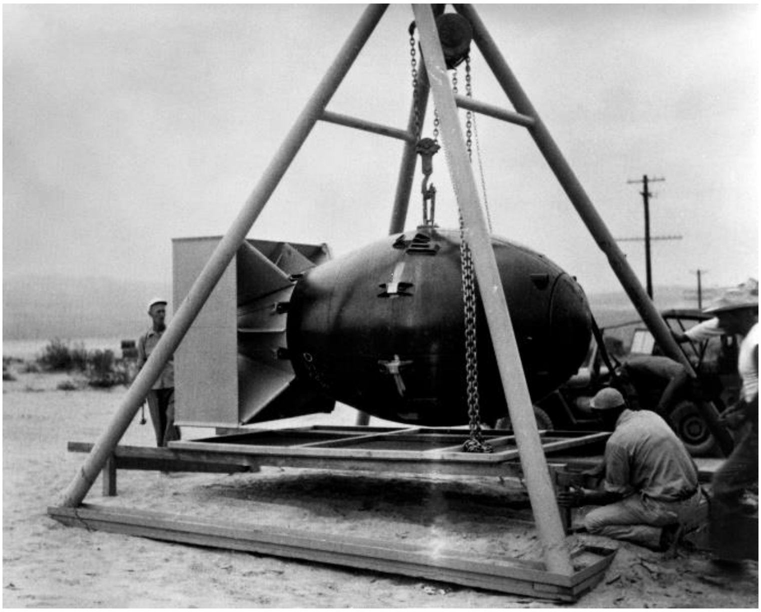
An interesting footnote to the atom bomb development effort: It began and ended without the services of the critical officer in charge of construction, Captain Oscar Sandquist. A quote from the first volume of the China Lake history might be in order here: "Within one year several hundred technical structures, hundreds of homes, service buildings, roads, facilities for telephones, electricity, sewage, water, and recreation facilities would appear where there had once been but a few scattered mines and homesteads."[87]

That was the year of Oscar Sandquist, which ended mysteriously on November 30, 1944, when he was transferred abruptly to a command in Alaska. His commanding officer exploded, prepared to fight the transfer; Captain Sandquist requested he not do so, and left, almost as quietly as he had come ten months earlier. His legacy of structures, roads, and facilities cannot be overstated.

NOTS military personnel, civilian scientists of Caltech, technicians, mechanics, accountants, and also clerical people worked usually dawn to dusk and often dawn to dawn for seven months on Project Camel. Although the district history states, with a reasonable grain of truth, "A great deal of the effort expended under Project Camel was insurance against accident, or failure, of similar work highly centralized at Los Alamos,"[88] it is unreasonable to discount the general daily (and nightly) efforts of those NOTS/Caltech personnel, and their contributions in

---

[86] *Manhattan District History*, 2.23.
[87] *Sailors*, 226.
[88] *Manhattan District History*, Foreword.



Charles and Thomas Lauritsen and several senior leaders contributed to Project CAMEL in design of the “implosion” version of the atomic bomb. Nearly the total workforce at the “Foothill Plant” worked on “Fat Man,” shown at the Salt Wells Pilot Plant.

terms of ideas, inventions, and imagination. Without them, the project as a whole might not have succeeded. They gave their all for seven months. While they worked, the war at sea continued; Iwo Jima and Okinawa in February and April 1945 were the last great island battles in the Pacific, with thousands of Caltech-developed rockets signaling the start of those battles. And then, in August 1945, history occurred.

The contributions of the California Institute of Technology and the U.S. Naval Ordnance Test Station to the national defense during World War II were of substantial significance. While they involved dedicated efforts by thousands of individuals, the two giants leading them were Dr. Charles Christian Lauritsen and Captain Sherman Everett Burroughs. Burroughs, a dedicated career naval officer, believed scientists and engineers should do their work without the military deciding which projects to pursue, and the military’s job was to provide practical ideas (such as his insights from combat aviation) and facilitate the work of the scientists. He found a perfect scientific partner in Lauritsen, an uncompromising man whose passion for the practical solution drove development initially in Pasadena and eventually in the desert. Although he retained his headquarters at Caltech, frequent communication and mutual confidence enabled the men to lead a joint mission throughout the war that long outlasted their brief relationship.

To summarize:

"… it can be stated that at the end of World War II, NOTS emerged not only as a lead laboratory of the Navy, but it could also claim the most completely instrumented ranges in the nation for rocket and midrange guided missile testing."[89]

Marie Broshious

A June 6, 1958 article in the NOTS *Rocketeer* featured Marie Broshious, who with Pay No. 10 laid claim to the lowest pay number of all current station employees. Broshious, the tenth Civil Service employee at the station, had arrived to work there June 1, 1944, a little more than six months after it was established at Inyokern in the Mojave Desert.

A native of Ohio, she had made her way to the station after two years with the Department of the Navy in Washington, D.C., spending another year along the way working for the Marine Corps in the town of Mojave, about 50 miles to the southwest. In the 1958 article, she was indirectly quoted as saying, "There wasn't much at China Lake then… except a few Quonset huts and an unending maddening supply of sand," which meant employees "walked to work in either ankle-deep sand or mud. There were no roads at the time."[90]

She and her fellow seven Supply and Fiscal Department employees made the walk from contractor housing to their single-room office in the Administration

[89] *The Grand Experiment*, 82.
[90] NOTS *Rocketeer*, June 6, 1958, 3.

Building to order the vast amount of materials required to build and operate a weapons testing station in the middle of a barren desert.

Like the station, the Supply Department grew over the next decade, and in March 1951 a group of department employees was transferred to the Pasadena Annex. Broshious transferred with them. (Just before moving, she was the proud recipient of the very first twenty-year federal service emblem presented at NOTS.) At the time of the 1958 article, she was a Supply section head. She continued to work in contract administration for the next two decades.

A July 6, 1973 article in the Naval Undersea Center's newspaper *Seascope* reported on the numerous Center employees retiring due to annuity increase incentives. It had been announced earlier in the year that the Pasadena Lab would close in 1974 and its functions would transfer to San Diego. With those two incentives, large numbers of Pasadena employees retired in several mass ceremonies, including Marie Broshious. She retired effective June 30, 1973, with a total of thirty-two years federal service, twenty-nine of them with various components of NOTS and one of its two successor organizations, the Naval Undersea Center.

5

Aftermath

The weather was typically fine in San Diego on August 6, 1945, with a mean temperature of 71 degrees Fahrenheit and no rain.[1] Captain Paul W. Hord began his fourth day as the fourth director of the U.S. Navy Radio and Sound Laboratory, after relieving Captain P.H. Hammond, who led the organization through most of the war and molded it into an effective technology developer in communications and radar. At various facilities on Point Loma and at the naval station, NRSL pursued its characterization of Navy surface ship antennas. In buildings nearby, its contract partner, the University of California Division of War Research, worked on its assigned technical efforts in studying the basic principles of underwater sound and developing sonars. Under the direction of Dr. Gaylord Harnwell, UCDWR was simultaneously pursuing its new high-priority requirement to document its history and accomplishments before going out of business shortly.

Inland at the Naval Ordnance Test Station at China Lake, daytime conditions were 83 degrees with moderate southwest winds and twenty-mile visibility—excellent for another day testing improvements to the airborne rockets Navy and Marine pilots had employed with deadly force four months earlier at Okinawa.[2]

In Pasadena, humidity and temperature were trading places, as the high-80s overnight humidity dipped to 26 per cent at 3:00 p.m. and the cool early-morning temperatures climbed to the high 80s by mid-afternoon. Most of the employees at the weapons plant on Foothill Boulevard were in the second month of a three-year contract working for General Tire and Rubber Company, while the professors-turned-weaponeers of the California Institute of Technology were considering the possibility of a return to their classrooms, possibly as soon as the fall semester.

At sea in the far western Pacific, forty-eight QLA sonars designed by UCDWR scientists were operating in the submarine fleet that had plagued the

---

[1] Weather Underground, Weather History for San Diego, California.

[2] Weather Underground, Weather History for China Lake, California.

home waters of Japan through the spring, sending 100,000 tons of the now-scarce shipping to the bottom in June alone.[3] Anticipating Operation Downfall, the invasion of the Japanese home islands planned for the coming autumn, the subs would guarantee that inter-island movement of troops and materiel at sea would occur only at great cost to the Japanese military—if it happened at all.[4]

Operation Downfall, however, would not happen. On that August morning, the B-29 Superfortress *Enola Gay* took off from the island of Tinian in the Pacific. On board that plane was the Navy's top ordnance expert, Captain William S. Parsons. Captain Parsons had made a brief stop at Inyokern, California, on his way to the island, visiting his old friends Dr. Charles Lauritsen, head of the California Institute of Technology rocket program, and Captain Sherman Burroughs, commanding officer of the Naval Ordnance Test Station. Whether the discussion of NOTS' work and the successful bomb test at Alamogordo two days earlier also included the visitor's itinerary for the next several weeks is not known.[5]

Over the Pacific shortly after takeoff on August 6, Captain Parsons and Army Air Corps Lieutenant Morris R. Jeppson armed a device nicknamed "Little Boy" in the bomb bay. The bomber flew northwest for six hours until it arrived above the city of Hiroshima on the home island of Honshu, and demonstrated to history that war had changed forever.

In the space of a few weeks, the war that had shaken the world for six years and killed millions of its citizens was over. The uncertainties and fear of the early days of the conflict, the steady growth of war-fighting capability and collective determination to overcome what often appeared impossible odds, and the final push to victory resulted in a sense of relief, completion, and satisfaction in the minds of most Americans.

There was also a sense of urgency: combat veterans hurrying home to the arms of excited loved ones; military efficiency and expediency in divesting of weapons and platforms of war; a rush to resume life interrupted by long years of doubt and rationing and separation. Hope soared. Babies boomed.

---

[3] University of California Division of War Research, *Completion Report*, 4.
[4] "Operation Downfall," *The American Experience*, PBS.
[5] J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Volume 2: The Grand Experiment at Inyokern* (Washington, D.C.: Naval History Division, 1978), 203.

Rear Admiral William S. Parsons

On Point Loma, in Pasadena, and at China Lake, things moved quickly as well. The Navy Radio and Sound Lab received a new director and new name within a few months. The Naval Ordnance Test Station witnessed a change of command. Caltech's Kellogg Lab was cleared of weapon-making detritus in order to welcome physics students of the class of 1949. War-time underwater sound researchers and weapons designers searched for textbooks and dusted off class notes as they prepared to resume roles as professors in Pasadena and Westwood.

The postwar world

Historians note crucial events at which one era ends and another begins, and the use of atomic weapons was surely such a turning point. The change is clearer, however, in hindsight than it might have been at the time. Everyone knew the bombings of Hiroshima and Nagasaki signaled a new world order, but the nature of that order was uncertain, because so much had already been upended by the tumult of World War II. Over succeeding days and months and years, four new realities would emerge, some gradually, some not, but all of them signaling a world vastly different than might have been anticipated before it went to war.

The first great change was certainty of the destructive capability atomic power conferred on those militaries possessing it. The explosive power of nuclear weapons was dramatic and fearsome; scientists and military planners, and for that matter any reasonable person, could envision in the destruction of Hiroshima and Nagasaki the potential for a next war like no other. Although conventional weapons had been employed effectively to obliterate cities such as Dresden and Tokyo just as thoroughly, the fact remained the United States of America possessed a weapon that was only the stuff of dreams of other nations. That nuclear monopoly reassured Americans in 1945, after years of uncertainty and fear.

Representing something of the flip side of that destructive power was the non-explosive utilization of nuclear energy, that is, the use of atomic reactors to power military ships and submarines, as well as to provide for everyday necessities such as electricity for homes and businesses. Although it would require several years to effect, it would become a remarkable new reality that signified a positive for a world which had endured for so long on negative.

The third force was geopolitical. The quick estrangement of the western allies from the Soviet Union, and the latter's determination to surround itself with Communist states both in Eastern Europe and in Asia, spurred competition for postwar advantage even before the war's end. After a horrifying four-year battle against Germany, during which twenty million of its citizens died, the Soviet Union entered the Pacific conflict in its last weeks, declaring war on Japan on August 8, 1945. One million Soviet troops entered Japanese-occupied Manchuria, eventually establishing a Communist government in North Korea. The Cold War redrew lines of adversaries, with America seeking to maintain military superiority.

The Office of Scientific Research and Development pioneered the fourth force, based on exigencies of the war effort: the three-way partnership among universities, industry, and the military that provided the intellectual, logistical, and operational expertise to invent, manufacture, and operate the most effective military technology the world had ever seen. In earlier times, it was routine for the military to imagine a solution to a problem and order the scientists or engineers to build it. OSRD's key innovation was, according to historian Irvin Stewart, "letting men who knew the latest advances in science become more familiar with the needs of the military in order that they might tell the military what was possible in science so that *together they might assess what should be done."* [emphasis added] [6]

[6] Irvin Stewart, *Science in World War II, Volume 7: Organizing Scientific Research for War: Administrative Framework of OSRD* (Boston: Little, Brown and Company, 1948), 6.

President Eisenhower would caution the nation about the dangers of a "military-industrial complex," but this partnership had proven so effective in a life-or-death struggle against fascism it seemed one of the great innovations of the war.

Those four realities would play a significant role in the futures of the Navy laboratories and their university partners discussed in this history. In a very real sense, the four translate into a single, inescapable truth that can best be stated in two simple words: technology rules. Captain Sherman Burroughs, speaking to his total staff of perhaps a dozen naval officers shortly after he arrived as the first CO of the Naval Ordnance Test Station, had said, "I don't like this situation any better than you do, but we just don't have Navy personnel to do the job—we have to use the brains of these professors to dream up solutions to our military problems."

With the Industrial Revolution perhaps as a precursor, World War II spurred scientific discoveries in physics, chemistry, acoustics, optics, and mathematics that translated into new platforms, devices, and weapons that, unfortunately, were often aimed at death and destruction. Nevertheless, despite their warfare implications, many of those discoveries resulted in civilian applications of incalculable value—safer air and sea travel, radio and television, medical technologies, computers. As we will see in our study of the California Navy laboratories, their technology development efforts went far beyond better and more efficient weapons.

Those laboratories contributed significantly to the four post-war realities:

Already the Naval Ordnance Test Station/California Institute of Technology team had played an essential role in loosing the atom's destructive power. Charles and Thomas Lauritsen had provided substantial scientific and managerial efforts in development of the nuclear devices that ended the war. The NOTS Salt Wells Pilot Plant had produced the high-explosive triggers for the "Fat Man" plutonium implosion bomb, and would remain the source of future components for such devices. (Manhattan Project leader Major General Leslie Groves was asked how many more nuclear bombs were in the U.S. arsenal, since millions of leaflets raining down on Japan in the three days between the bombings of Hiroshima and Nagasaki suggested there were many. His response: "We have just begun to use this weapon…" At the time of his statement, there might have been a handful of bombs to drop, but more importantly, the Salt Wells plant was on-line and in succeeding days, many more bombs could have been available in short order.[7])

[7] *The Grand Experiment*, 205-207.

Only four years after the first bombs were dropped on Japan, the Soviet Union ended the U.S. monopoly in that area, detonating one of its own in the high desert of Eastern Kazakhstan.[8] Salt Wells would become a major asset in assuring, if not monopoly, then at least parity.

The peaceful use of nuclear energy had a curious effect at the Navy laboratory on Point Loma. As mentioned earlier, Dr. Waldo Lyon had, in the course of surveying potential harbor defense methodologies in Puget Sound, collaborated with Canadian scientists and become interested in the effects of cold water on underwater acoustics. It was a short step from that interest to his life-long vocation of Arctic submarine warfare, a project only made reasonably feasible when the United States Navy built a submarine that was nuclear-powered. That submarine, USS *Nautilus* (SSN-571), the world's first nuclear vessel, figured prominently in the achievements of Dr. Lyon. Those will be related in detail in the next chapter.

With the success of *Nautilus*, the Navy began building entire classes of submarines, aircraft carriers, and surface combatants powered by nuclear energy. While that trend continues to the present for the carriers and subs, there were few advantages for nuclear power plants on smaller surface ships, and most of the Navy's surface ships today use conventional systems such as modern diesel or gas-turbine engines. In 1945, however, the national imagination burned with visions of nuclear-powered ships, airplanes, and space vehicles.

The Soviet Union and its immediate post-war actions have been the subjects of myriad books, magazine articles, TV documentaries, and Hollywood movies. Those are outside the scope of this history, with an exception: every Soviet war platform or weapon achievement since World War II has been countered by the U.S. with a similar, stronger-better-faster platform or weapon, and the two California laboratories were often in the thick of that countering. A faster, deep-diving class of Soviet submarines resulted in a faster, deeper-diving torpedo developed in Pasadena. Electromagnetic pulse technology engendered radiation-hardened electronics from the Point Loma Navy laboratory. More and faster enemy aircraft and missiles were tracked effectively by faster and higher-capacity command and control display technology.

The hottest period of the Cold War came during the Korean Conflict, and it included abundant use of weapons designed and tested in the desert. Between 1950

---

[8] "This Day in History—August 29, 1949," The History Channel, accessed January 5, 2015 at http://www.history.com/this-day-in-history/soviets-explode-atomic-bomb.

and 1953, Navy and Marine pilots fired 272,000 rockets on that small peninsula, substantially more than in all of World War II. On May 1, 1951, aircraft from the carrier USS *Princeton* (CV-37) breeched the flood gates of the Hwachon Dam, the only use of aerial torpedoes (produced in part by NOTS) in that conflict.[9]

The separation of the warfighter and the civilian scientist was a substantial one during the First World War. As noted earlier, Caltech principals haunted the halls of the Pentagon during the earlier conflict, offering the scientific services of their institute, with little more than a lukewarm reception. In the second world-wide conflict, Dr. Bush's NDRC/OSRD organization had literally thousands of university professors and scientists working sometimes around the clock to provide the latest and greatest technology to deal with a new enemy platform or weapon, often working side-by-side with the military. Nowhere was that collaboration between military personnel, civilian Navy and university scientists, and contractors more obvious than at the California Navy labs.

With the lessons learned from the war, senior military officers were eager to discuss their challenges with civilian scientists and seek their advice and solutions.

Each new rocket development from the California Institute of Technology resulted in demands for thousands, or tens of thousands, of them, often *per month*, and when the institute's technicians, clerical staff, and mail room employees working three shifts a day were unable to comply, hundreds of small Pasadena and Los Angeles manufacturing firms turned to in order to fill the requirements.

That paradigm would grow substantially after the hostilities ended.

Postwar operations on Point Loma

As the drawdown following Japan's surrender continued, the Point Loma Navy laboratory developed and distributed "a general report" to the individuals and organizations to which it was mostly closely connected. (As noted previously, Captain Hammond had terminated his biweekly reports to the Bureau of Ships in June 1945. He had stated in the document there was no longer a need for a widely circulated report of this type.) Specified as covering the three-month period ending 30 September 1945 (so, essentially, the end of the war), the new report was a more rounded statement of capabilities, discussing the lab's three departments—systems

[9] Naval Historical Center, *United States Naval Aviation 1910–1995 Part 7—Korea.*

engineering, development, and research—and selected projects (formally termed and numbered as "problems") related to those departments.

The introduction was valuable for explaining purposes and relationships:

> To help in the discharge of its responsibility for the design, procurement, installation, and maintenance of electronic equipment, the Bureau of Ships maintains the U.S. Navy Radio and Sound Laboratory at San Diego. Under the technical direction of the Bureau, the Laboratory conducts special investigations and development closely coordinated with the needs of the Fleet.[10]

In the detail that followed, the report noted the Systems Engineering Department was responsible not only for improving individual shipboard electronic components, but "also in studying the effectiveness of all radio, radar, and sonar units working simultaneously under operating conditions."[11] Problems addressed by the department were those worked before and throughout the war—B21CD and B22CD, "Antenna Directivity and Ship Type Antenna Systems."

Urgent war requirements to develop new technology rapidly, the report stated, had the end result that

> radio, radar, and sonar devices multiplied like rabbits, so that today almost every ship carries an imposing thicket of wiring and antennas. Many of these antennas are in competition for favored positions, and frequently two or more pieces of equipment interfere with each other's operation.

The report continues optimistically that with less time pressure "it should be possible to study the needs and problems of every kind of ship, and then to evaluate, modify, and locate its electronic equipment most effectively."

Discussed as one of the most important aspects of system engineering was evaluation of antenna directivity. Although that could be done using the actual ship, "scale models are expected to play an important part in the investigations, since work with models has several advantages." In addition to the obvious savings in time and money, the ease and simplicity of modifying models was mentioned. Initially, there was only one model, of USS *Gregory* (DD-802), but engineers had determined credible approaches to using it for tests on another destroyer class as well. Since measurements had already been made on the actual ship, they were able to use that data to check the validity of using a model instead.

The report posed several questions the antenna engineers were seeking to

---

[10] U.S. Navy Radio and Sound Laboratory Quarterly Report, September 1945, 3.
[11] Quarterly Report, 4.

answer, such as how to build a ship model to simulate electrical characteristics of the ship itself and how to set up a test range to simulate ground (actually ocean surface) conditions accurately. They were questions which the system engineers would pursue energetically during the months immediately after the war.

The Development Department was responsible for designing and building new equipment and improving existing devices. Their assigned problems included modification of a search radar to follow upper air sounding balloons in rough sea conditions or cloud cover under which the usual means (theodolites) failed and development of "jellyfish" transponder beacons, devices dropped by a pilot plane to guide following flights to difficult targets. Department engineers also modified an existing radar to allow it to track trajectories of mortar shells and from those to deduce the mortar location so it could be destroyed.

As was often the case, a Navy sponsor-provided task lent itself to civilian applications as well as military ones. One of the department's efforts was development of a precision Racon system for marine navigation, equally useful for civilian and merchant ships. As a result, a Coast Guard officer was assigned to NRSL for temporary duty, to support ship-to-shore testing.

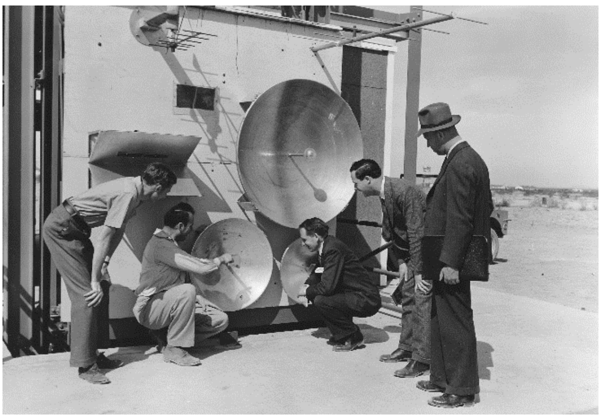
As described earlier, the University of California Division of War Research developed a number of training devices for the fleet, as one of its contractual obligations. With the cessation of hostilities, this training ended; however, the devices were still available for use. Although they had been used extensively in training, the devices lacked the means to instruct in determination of depth. NRSL worked with UCDWR and the West Coast Sound School to modify the group trainer for this purpose in order to train future generations of sonar operators.

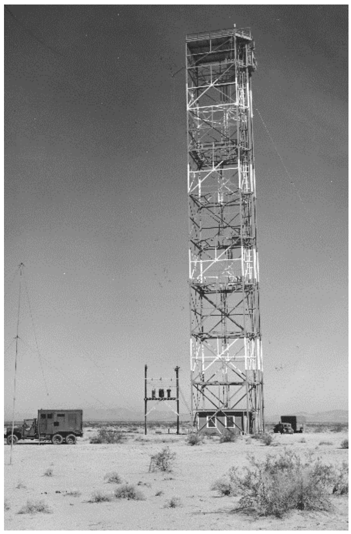
The NRSL Research Department was "properly concerned with principles and laws, with determining what may be possible... in physics, oceanography, meteorology, mathematics and allied sciences..." After developing new equipment during the war, the future would result in "renewed emphasis upon basic scientific problems facing the Laboratory's development and system engineers."

In order to address the assigned problem of propagation of high frequency electromagnetic waves, the laboratory erected a range—in addition to locations in San Diego and San Pedro—in Arizona, at a desert site called Sentinel. Acknowledging substantial British research to predict radar performance, the NRSL group elected to refrain from their method of making simplifying assumptions and used instead an empirical method, making controlled observations to gather facts, in the belief that development of "appropriate mathematical formulation of theory should follow. The main objective of the investigation is to find answers to questions important in design, development, and operation of radar and communication equipment."[12]

After work close to home "to determine the distribution of radio energy in the lower troposphere under the varying weather conditions prevailing in this area,"[13] studies were moved to the Arizona desert, where predictable meteorological conditions of ground cooling and rapid radiation of heat into space after sunset resulted in "an almost perfect natural laboratory for the investigation of electromagnetic wave propagation under conditions of a very low level temperature inversion."[14] The project included setup of a fifty-mile one-way transmission link path, with two-hundred-foot towers erected at each end and at the midpoint. Work at Sentinel would continue well into the 1980s.

Perhaps the department's most important effort was continuation of the NRSL and UCDWR basic research in underwater sound: "… studies in sound refraction,





As NRSL became the Navy Electronics Laboratory, Point Loma engineers moved to the Arizona desert to set up a transmitter complex and three 200-foot-high antennas 25 miles apart to study basic electromagnetic wave propagation.

---

[12] Quarterly Report, 15.
[13] Quarterly Report, 16.
[14] Quarterly Report, 18.

reflection, and absorption phenomena are an important part of NRSL's long-range engineering program."[15]

Among a number of other important projects, the Navy lab's post-war tasking included providing assistance to Scripps, which as discussed earlier had made substantial progress in predicting sea and swell conditions essential to amphibious operations. NRSL was directed to use its specialized facilities and personnel to support this ongoing effort.

Bureau of Ships direction

The introduction quoted above made clear the Navy Radio and Sound Lab was a Bureau of Ships laboratory, funded to perform basic studies as well as equipment development considered important to the future Navy. Quite possibly at bureau recommendation, the Secretary of the Navy changed the organizational name: on November 29, 1945, NRSL became the U.S. Navy Electronics Laboratory (NEL). The new organization's mission was "to effectuate the solution of any problem in the field of electronics, in connection with the design, procurement, testing, installation and maintenance of electronic equipment for the U.S. Navy."[16] (Actually, the "new" organization was merely the old organization with a new name; in the summer of 1946, when UCDWR was disestablished and its projects became part of NEL, *then* it became a new organization),

The emphasis during the war, perhaps demonstrated more in the Caltech/NOTS environment, but still significant at NRSL and UCDWR, was expeditious reaction to emerging requirements. In a *Journal of Applied Physics* article,[17] the second NRSL director had cited his staff's immediate response to fleet requests, including informal ones that surfaced while his engineers were aboard ship for a planned study or installation. With the end of war urgency that equated delay with loss of battles and more casualties, there was time to consider more objectively how an organization like a Navy laboratory should operate.

---

15 Quarterly Report, 19.

16 Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*, 24.

17 Captain P.H. Hammond, USN (Ret.), "The U.S. Navy Radio and Sound Laboratory," *Journal of Applied Physics*, Vol. 15, March 1944, 240-242.

The fourth laboratory director, Captain Paul W. Hord, foresaw that operation as involving less fleet support and more basic research:

> To fulfill its mission, the Laboratory must remain a scientific institution wherein scientific work is performed by scientists under the direction of scientists. The future of NEL depends solely on the scientific results it produces. The stature of NEL is directly proportional to the stature of its scientific personnel.[18]

Thus, there would be less emphasis on improving existing systems and more on developing new technologies over the longer term. In practice, he knew, this meant retaining and hiring the most accomplished scientists possible to do research and hiring fewer of the people needed to get something into the fleet fast.[19]

Following hard on the heels of a new name and mission was new direction, stated in a memorandum from the chief of the Bureau of Ships (but signed "By direction" of Captain Rawson Bennett, head of the Electronic Design Division),[20] establishing lab tasking in terms of basic projects the bureau wanted addressed. The memo noted the projects were "broad in scope, so that the Director... may plan and implement the most effective organization of personnel and facilities for carrying out the work of the Laboratory." Substantially significant, particularly after the NRSL Quarterly Report of 30 September 1945, was the statement "All problems presently assigned to the U.S. Navy Radio and Sound Laboratory are superseded by these new projects and problems." Also pertinent was direction that all work being done by UCDWR on any of these problems was to be transferred to the Navy laboratory, on a schedule mutually agreeable to the two organizations.

Captain Bennett also advised of the probability the University of California would establish programs for basic research in underwater sound, and an R&D program for antenna research, both of which would be pursued cooperatively with the Navy lab. (The 30 September 1945 NRSL Quarterly Report mentioned fourteen engineers from the University of California at Berkeley had visited the model range to gain an understanding of Navy ship antennas and they were now engaged in antenna research.[21])

Citing the cadre of UCDWR scientists who had developed expertise in design

---

[18] *Fifty Years of Research and Development*, 24.
[19] Howard O. Welty, "S.D. Becomes Research Center for Electronics," San Diego *Union*, September 29, 1946.
[20] Bureau of Ships memorandum to Director, U.S. Navy Radio and Sound Laboratory, dated 7 December 1945.
[21] Quarterly Report, 6.

and construction of crystal transducers during the war, Captain Bennett sought the Navy lab's continuing association with them to continue that work.

The main body of the memorandum provided a list of eighteen projects, several of them continuations (although newly numbered) of war-time efforts. For example, Projects D1, 10, 12, and 13 directed efforts toward improving sonar devices, including QLA installations, while Project D4 addressed antenna studies (the long-pursued efforts on directivity characteristics of ship antennas and the general improvement of those antennas). The antenna directivity studies were tied specifically to the use of ship models.

Additional tasking included studying the basic physical phenomena of radio waves propagating over sea and land, training fleet personnel in operating electronic systems for tactical uses, development of electronic equipment for air-sea rescue, and one to "Furnish advice and assistance to the various activities of the Navy Department and their contractors as approved by the Bureau of Ships." The latter was reminiscent of a work objective given to individual organization employees in later days: "Perform other duties as assigned." Both were essentially catch-all phrases that allowed the Bureau of Ships and individual supervisors to re-think priorities based on emerging requirements and change the lab/employee tasking without writing a new mission statement or position description.

First antenna conference

The assignment of new tasking by the Bureau of Ships was a clear indicator the Navy laboratory on Point Loma, established eighteen months before the start of World War II, would continue operating for the foreseeable future after the war. To emphasize the long-term commitment of the Navy to the lab, a major conference was held at NEL in mid-January 1946 "to promote better understanding of the Bureau of Ships long term antenna problem and effect closer liaison between manufacturers and service laboratories. This problem was assigned the Navy Electronics Laboratory in May 1945."[22]

The NEL director and his deputy attended, as did Dr. Gaylord P. Harnwell,

---

[22] "Improvement of Shipboard Antenna Systems. Summary of Discussion at the Navy Electronics Laboratory," 16-18 January 1946, 1. The NEL *Station Journal* records follow-on antenna conferences at the lab annually for the next six years (1947-1952).

still the UCDWR director, and representatives from the U.S. Navy Underwater Sound Laboratory, the Naval Research Laboratory, Bureau of Ships, Bureau of Aeronautics, "Nineteenth Fleet," and the University of California (Berkeley).

The senior BuShips rep, Commander T.W. Rogers, advised attendees the conference was called by his bureau and NEL to address one of the assigned problems, which he characterized by saying most Naval Academy attendees had heard about it in a text book, which stated, "'That the battleship has a multiplicity of antennas.' That was about the extent to which the problem was visualized. They should survey the antenna situation now." He noted well-meaning wartime efforts during ship overhauls to relocate antennas and try to improve their performance, without the time or appropriate equipment or facilities to do that, adding,

> In passing I would like to point out that the Electronics Laboratory here probably did more good work along that line than any other single agency that I can name. In spite of this good work we didn't get very far with the actual measurement of the antennas and their radiation characteristics and didn't get all the answers.[23]

Following him, W.F. Squibb, head of the NEL Radio Division, advised the BuShips problem assigned to NEL was

> responsibility for the preparation of type plans for an antenna system for each type and class of vessel. Initially, the problem involves getting on paper present antenna installations and correcting obvious defects. The long-range program will involve the development of new antennas and their coordination into an integrated system. The integrated antenna system will include all antennas used for the radiation of electromagnetic waves.[24]

Another BuShips officer explained NEL would break down the assigned problem into smaller tasks and determine what other service laboratory or company could reasonably handle them, noting it was impossible for one organization to manage all the work involved. A small bit of potential claim-staking by the Naval Research Laboratory representative, who suggested his organization "should be made the agency for the coordination of antenna research in the Navy," was squashed quickly by the BuShips officer, who called the cited Chief of Naval Operations memorandum merely a recommendation.

A wide-ranging discussion ensued during the meeting about technology developments, expertise available from the organizations of the various attendees, and task assignments. The University of California was assigned nine tasks, which were discussed at length; and NEL forwarded seven tasks to the Bureau of Ships

---

[23] "Improvement of Shipboard Antenna Systems…" 5.
[24] "Improvement of Shipboard Antenna Systems…" 6.

to assign to other federal agencies or contractors. These tasks included use of an aircraft to determine antenna directivity patterns, specification for a polar type recording instrument for use in drawing accurate representations of those patterns, and development of a material which would simulate the ocean surface at the Model Range.

Shipboard Antenna Model Range

The Shipboard Antenna Model Range had been set up originally in August 1944, located about a mile southwest of the NRSL headquarters building, to study shipboard antenna directivity and to provide a means for antenna performance evaluation and improvement.[25] The first models, fairly crude in design, were made of wood sprayed with a coating of brass to provide conductivity. Unfortunately, the conducting surface deteriorated rather quickly, so range personnel sought a more permanent modeling method, settling on thin sheets of brass covering wooden blocks shaped like a ship.[26]

Of significant importance was the ground plane, which had to simulate the electrical properties of the ocean surface. The initial effort on this was a circular sheet of lead, sixteen feet in diameter, with a thirteen-foot-diameter pool of mercury under it.[27] Antenna arrays were rotated while in contact with the pool, with energy radiated from a remote source nearby. The ground plane was substantially enlarged several years later to a 160-foot-diameter slab of pre-stressed concrete sprayed with a coating of thin lead film. In the center was a twenty-two-foot-diameter platform flush with the concrete surface, on which the model was rotated. (The initial "rotating" was done by engineers and technicians physically lifting the models and re-positioning them to the desired angles. Subsequently, a turntable was constructed, with a work space for instrumentation underneath, to automate the rotation.)

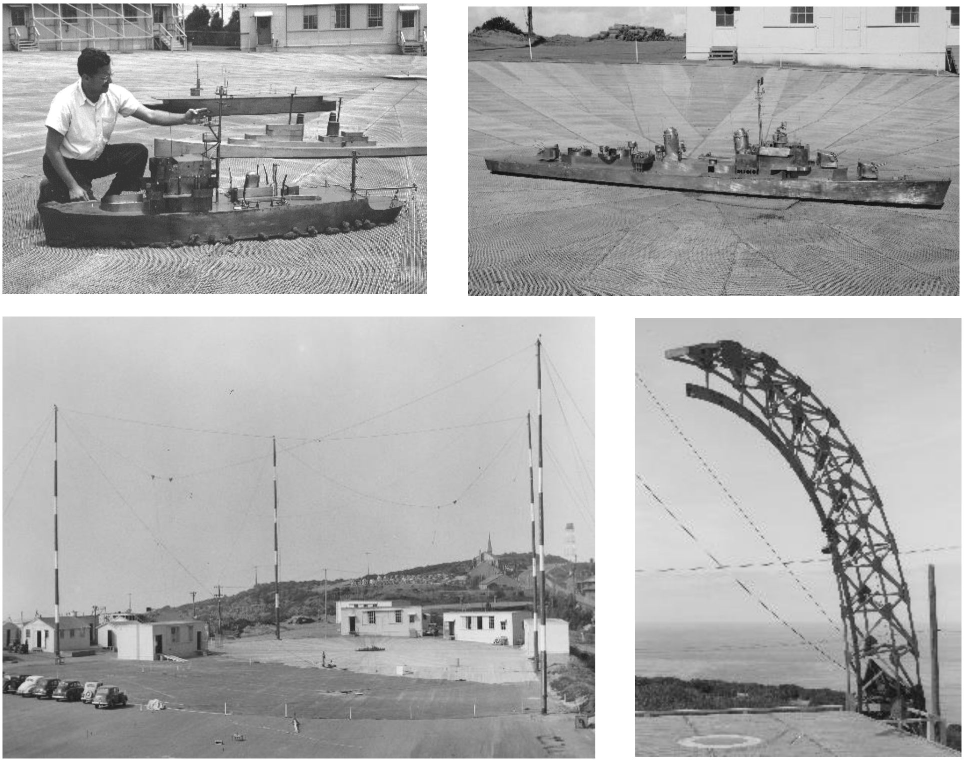
With the subsequent realizations that use of mercury and lead for these purposes was environmentally harmful, appropriate soil remediation of the area

---

[25] W.B. Wells, USNEL Report No. 1, "Ship Antenna Systems Model Range—Instrumentations & Techniques," 28 March 1947, Preface.
[26] NEL technical brochure "Shipboard Antenna Model Range," ca. 1960.
[27] Wells, USNEL Report No. 1.

was completed in the early 2010s and a new ground plane of concrete topped by sprayed aluminum was installed, with copper sheeting on the turntable.[28]

Following the antenna conference, the model range was expanded. A set of ninety-five-foot-high poles was erected around the edges of the ground plane, with the transmitting unit supported on wires between a pair of the poles, maintained at a distance of approximately eighty feet from the model, at various heights and angles above it.[29] In 1948, the first of a series of curved structures, termed "arches,"



Three examples of evolutionary development of model ship sophistication (top left) and a fourth of USS *Tucson* (CL-98) (right). In 1946, 95-foot telephone poles were erected to position antennas on wires suspended high overhead a model under test. Two years later, the first antenna arch was constructed.

[28] Dr. Stephen Russell e-mails to Tom LaPuzza, January 25, 2020.
[29] NEL Report No. 1, 4-5.

was erected for vertical movement of transmitting and receiving antennas, this one fashioned of wood and approximately twenty feet high.[30]

The range is employed for study of antennas operating between communication frequencies of two and 400 megahertz. In the range of 2 to 30 MHz, the ship and major elements of its structure (superstructure, masts, guns) are potential radiators, so at these frequencies "the entire ship must be modeled."[31]

The NRSL quarterly report of 30 September 1945 had suggested somewhat theoretically one-twentieth scale models and advised that as the ship dimensions were scaled down, so the radio frequencies must be scaled up to duplicate behavior of radio waves. After some fairly basic calculations, the scale of one forty-eighth was adopted for general ship models:

> … if we scale it [the ship model] to one forty-eighth size physically, we have to increase the frequency by forty-eight times, and that tends… to be pretty convenient, both in terms of how big your ship model is going to be and what your frequencies are going to be. So, for example, our carrier models are about the same size as our turntable right now, about twenty-two feet long. So that's physically a good size for the ship models, and then the frequencies that we end up measuring—the two to thirty megahertz times forty-eight—ends up being a very convenient frequency range to measure with our instrumentation… 96-1440 megahertz.[32]

The brass ship models themselves are things of beauty. Created by master model makers in a shop located between the range and Cabrillo Memorial Drive, they are painstakingly crafted of wood plated with a thin exterior layer of brass, so detailed that anything larger than a foot in length on an actual ship is scaled on the model. Gun turrets can be rotated and guns raised; aircraft carrier deck elevators can be raised or lowered. Anything that could affect radio propagation is replicated in exact one forty-eighth scale.

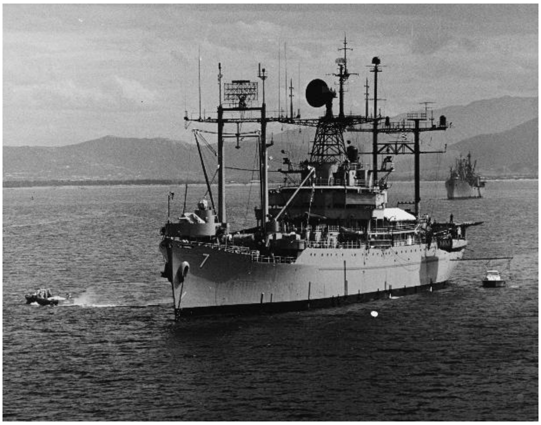
In normal testing, a ship model is placed on the turntable and the antenna on "the arch" (see footnote above) at the edge of the range transmits or receives signals, allowing range personnel in a nearby control room to measure the strength and behavior of radio waves propagating back and forth between the antenna and the model. During actual measurement, the ship is stationary:

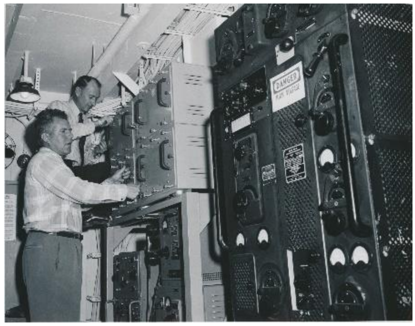
> The azimuthal antenna is moved to different heights [on the arch] and/or the frequency is

[30] As the longest-lived of all the Point Loma lab's specialized facilities, the model range would be upgraded over time, with a new "zenith arch" installed in 1958 (See next chapter) and a three-legged fiberglass-reinforced plastic structure in 1994 (See Vol. II).
[31] NEL Report No. 1, Preface.
[32] Jodi McGee directed interview conducted by Tom LaPuzza August 24, 2016, 17-18.

changed, and then the ship model is repositioned to the next position. Although they can do the measurements while rotating [the model on the turntable], they usually don't, but a lot depends on what they are measuring, whether it's radiation pattern, electromagnetic interference, or antenna coupling or losses.[33]

Bureau of Ships optimism for the early modeling effort to improve shipboard antenna efficiencies was well-founded: to cite one example, in 1951 the USS *Mount McKinley* (ACG-7) was re-commissioned with one-third the number of antennas originally required, with no loss of communications effectiveness.[34]





USS *Mount McKinley* (ACG-7) at sea. New radio equipment installed by NEL personnel allowed the ship to communicate with equal effectiveness using only one-third of the previous number of antennas.

Other noteworthy projects

UCDWR, with personnel strength at its maximum nearing 600, pursued primarily sonar-related research, but also had the resources to study other acoustically based projects. Based on Bureau of Ships direction, NRSL and (in the late fall of 1945) NEL assumed responsibility for these efforts. Two of the university projects the Navy continued were IFF and SOFAR.

[33] Dr. Stephen Russell e-mail to Tom LaPuzza, January 24, 2019.
[34] *Fifty Years of Research and Development*, 26.

During the war, division scientists had begun work on an electronic capability which enabled operators in aircraft or ships or on land to query a flying aircraft and receive a positive response if the aircraft was friendly. The preliminary intent was to cut down if not eliminate friendly fire casualties. Several other countries (Great Britain and Germany among them) worked on similar technology during the conflict. Unfortunately, the title that evolved and eventually stuck—Identification Friend or Foe (IFF)—is somewhat misleading, in that it suggests a binary solution to the query: a response back from the aircraft confirms it is friendly, no response implies it is not. That is not necessarily true, since a non-response *could* be a foe; it could also be a non-combatant or a friendly aircraft whose response signal generator is not functioning, or turned off. And, in fact, a clever foe could develop a response signal generator to provide a positive (i.e., friendly) response.

IFF was at first a simple system sending a code in response to an inquiry signal. After the war, NEL scientists developed more sophisticated identification features, enabling friendly aircraft to send detailed information—the forerunner of modern air traffic control systems that process details about multiple aircraft size, speed, and direction in an instant. The NEL system completed operational evaluation in 1951 and soon became operational with all U.S. and NATO forces. In 1958, an aircraft identification system based on original laboratory designs was installed in all U.S. military aircraft, all ground radar sites, all U.S Navy ships, FAA tracking radars, and all new commercial aircraft.[35]

Another UCDWR research effort was the Sound Fixing and Ranging (SOFAR) system, developed for location and rescue of survivors of ships and aircraft that went down at sea. The survivor was expected to drop a small depth charge into the water; it would sink to a depth of 3,500 feet, the optimal depth for underwater sound transmission, and explode. Hydrophones placed at that depth would receive sound waves from the explosion, triangulate on it, and alert rescuers to the location. NEL completed the project by establishing three radio direction-finding stations in the eastern Pacific to provide receivers for the emergency signal. The system was later used for research in underwater sound.

One other immediate post-war project in which the lab participated bears mentioning.

[35] NEL Command History 1940-1958.

Operation Crossroads

In 1945, America had demonstrated vividly the power of the atomic bomb, but possessed little knowledge about its effects beyond the devastation wrought on Hiroshima and Nagasaki. What would happen to ships and their equipment at sea if a nuclear explosion took place several miles distant? How big a wave would such an explosion make? Would ships and the environment become radioactive? If so, at what distances? How might an airburst differ in effect from an undersea blast, such as those contemplated in early designs for nuclear depth charges?

In mid-1946 the Navy sponsored Operation Crossroads to research these and other questions at Bikini Atoll in the Marshall Islands. More than ninety ships were brought to the target area, including obsolete U.S. capital ships, older U.S. submarines, and captured German and Japanese vessels.

Commander Roger Revelle, previously assigned to the Point Loma lab and still in uniform at the Bureau of Ships in Washington, was responsible for the oceanographic and geophysical components of Operation Crossroads.[36] Revelle's team would study the diffusion of radioactive wastes and other environmental effects of the explosions.[37] He contacted NEL and requested scientists to measure the heights of waves generated by the tests. Dr. Waldo Lyon, who had worked on several projects with Revelle during his tour at the lab, was selected to head the measurement team; the other members were Ralph Doherty and Leighton Morse.

For the first test, the team surveyed the atoll's beach in late May and set up poles to record heights of waves reaching shore. They also installed recording equipment on a number of the "fleet" of ships anchored in the lagoon. On July 1, 1946, a B-29 bomber dropped a twenty-three-kiloton nuclear device that exploded 518 feet above the surface of the lagoon. The day after the test the NEL personnel retrieved data from the recorders on the poles at the beach, and after a week they were able to board the ships, mostly destroyed, to recover those recorders. That effort took them nine days.

On July 25, the second test involved another twenty-three-kiloton device,

---

[36] Deborah Day, "Chronology of the Life of Roger Revelle," Scripps Institution of Oceanography Archives.

[37] Deborah Day, "Chronology of the Life of Roger Revelle," Scripps Institution of Oceanography Archives.

detonated ninety feet underwater. According to William M. Leary, author of *Under Ice*, a volume on Dr. Lyon, BAKER produced "the greatest waves ever known to humanity." The unprecedented radioactive contamination of the ships prevented Dr. Lyon from boarding them until August 1. Then, wearing canvas boots and heavy gloves, he was able to recover data from the recorders that survived the explosion. He subsequently conducted a survey of the explosion-generated wave impact on the island of Bikini.

Commander Roger Revelle receiving Secretary of Navy commendation for leadership of Operation Crossroads.

It was a substantially sobering experience for Lyon (and also, he suggested, for his fellow spectators): "Everyone who witnessed it was certainly impressed—that's a very weak word in this case—by the magnitude of the energy released by the bomb and the destruction that could be wrought…. After witnessing that I never wanted to see them ever used."[38]

[38] *The Reminiscences of Dr. Waldo K. Lyon*. Interviews conducted by Commander Etta Belle Kitchen, USN (Ret.) (Annapolis, Maryland: U.S. Naval Institute, 1972), 13.

University of California Division of War Research

As described in Chapter 1, the University of California Division of War Research was created in April 1941 as one of two organizations to address the menace of German submarines in the Atlantic and the Caribbean Sea. Originally established by the National Defense Research Committee, it was funded throughout by the NDRC successor Office of Scientific Research and Development. On March 1, 1945, OSRD turned the contract over to the Navy Bureau of Ships, recognizing a significant amount of the university's projects during the war had potentially lasting value for the Navy and should be continued. Among its responsibilities assigned when BuShips took over (and slightly amended) the contract, the division was charged with developing a final report "in case necessity required the organization of a similar laboratory" in the future.[39]

The bureau chief also assigned contract responsibilities to the director of NRSL, first Captain P.H. Hammond, who had led the Navy laboratory throughout the war and worked closely with UCDWR personnel during that time, and then to Captain Paul W. Hord, who succeeded him in August 1945. With the war winding down, the robust publications organization UCDWR had built up during its tenure began compiling a rigorous report to respond to that requirement.

In a section of that report titled "Terminal Dispositions," there is a summary description of the processes whereby the division continued and closed out its work, which was essentially based on task orders written by the chief of the Bureau of Ships to complete projects still underway. The new working relationships among the bureau, UCDWR, and local Navy organizations, particularly the Radio and Sound Lab, are cited in several instances as "intimate" and highly cooperative.

In terms of specifics, the programs were turned over to NRSL (or NEL after November 29, 1945), with the majority of the effort focused on the write-up of reports to ensure the data gathered and conclusions drawn by lengthy and painstaking scientific research were not lost in a hasty going-out-of-business-sale fashion. The Sonar Devices Division published monthly progress reports until late in the year; the last monthly report of the Sonar Data Division was dated February 1946. Both divisions continued to the last issue reporting in substantial technical detail the results of their ongoing research, which they were concluding now.

---

[39] UCDWR *Completion Report*, 5.

Patentable discoveries were reported during the contract transfer from OSRD to the Navy, and a second summary was prepared in early 1946 as the majority of the programs were transferred to NEL.

The "dispositions" section ends on a very positive note: "UCDWR is greatly indebted to the sympathetic understanding and cooperation in these negotiations exhibited by the Director, NEL, (as Technical Inspector) and his staff."

An equally positive note occurred as Dr. Harnwell was wrapping up his affairs prior to returning to the academic world. He was invited by the Commander, Submarine Squadron Five, to visit the submarine tender USS *Fulton* (AS-11) in San Diego harbor, where he was given a plaque stating, "Presented in appreciation of outstanding services rendered by the UCDWR Group to the Submarine Force Pacific during World War II." In presenting the plaque, the naval officer stated the average layman would not understand what the group had done, but members of the submarine force knew only too well the contribution UCDWR had made to their success.

On June 30, 1946, the University of California Division of War Research ceased to exist. After a little more than five years of scientific endeavor by some hundreds of university professors and scientists (and "housewives and high school students," according to Dr. Harnwell's preface to the "UCDWR Roster 1941-1945"), nearly a thousand technical reports, thousands of experiments to prove or disprove working theories, and numerous sea voyages brief and extended, the staff disbanded.

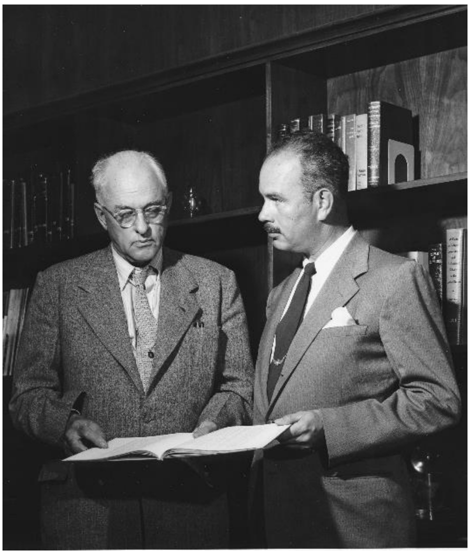
UCDWR leadership moves on

Several months before, Dr. Harnwell had returned to the University of Pennsylvania, where he headed the Department of Physics. In 1951, he returned to the Navy lab on Point Loma representing the National Academy of Sciences for a joint study, resulting in NEL Report 265 of 21 August 1951: "The Cooperative Research Program of the Navy Electronics Laboratory and the National Research Council on Bottom Sea-Mine Countermeasures." He later served as president of the University of Pennsylvania.[40] And, as will be discussed in Chapter 7 below, he headed a Bureau of Ships-funded study on the future direction of the Navy's torpedo development programs.

Dr. F.N.D. Kurie headed the UCDWR Sonar Devices Division, and later served as associate director until the division was dissolved. (Interestingly, the *Completion Report* states Dr. Kurie succeeded Harnwell as director when the latter returned to Pennsylvania in January 1946. Preponderance of the references, however, state it was Dr. Carl Eckart, the other associate director, who succeeded to the directorship.[41])

After the war, Dr. Kurie moved east to work for the Naval Research Laboratory, managing its Nucleonics Division. In that capacity he visited NEL in the spring of 1953; a few months later he returned as the deputy superintending scientist of the Point Loma laboratory. Apparently, it was a succession planning effort, because the superintending scientist, Dr. Joseph Maxfield, retired on December 31 and Dr. Kurie became the lead NEL civilian on January 1, 1954.

Until that time, for the thirteen-plus years of its existence, the organization's



Shown in August 1953 are Dr. Joseph Maxfield, NEL superintending scientist (left) and Dr. F.N.D. Kurie, who would succeed him on January 1, 1954. On that date, Dr. Kurie became the first NEL technical director.

[40] Wolfgang Saxon, "Gaylord Harnwell, Physicist and President of Penn, Dies," The New York *Times*, April 19, 1982.

[41] *Completion Report*, 30. See also: Fred Spiess and William Kuperman, "The Marine Physical Laboratory at Scripps," *Oceanograph*y, Vol. 6, No. 3/2003.

military leader had been titled "commanding officer and director," and the lead civilian was "superintending scientist." With the elevation of Kurie to the lead position, the title "technical director" was used for the first time. He continued in that position until ill health forced his retirement in September 1960.

Dr. Vern Knudsen, who had been selected to lead the war division but after a year was called to the New York headquarters of the Office of Scientific Research and Development, returned to UCLA to continue his leadership of the Graduate Division. Eventually he became university chancellor. His expertise in acoustics had resulted in his planning the first sound stages of a number of Hollywood studios, including MGM and Paramount; he later consulted on the acoustics for the United Nations headquarters building.

As the UCDWR work ended, a number of its technical personnel resumed their professorial vocations at UCLA and various other universities, while some made the decision to continue their Navy support work and accepted employment at NEL. For them, it was something of a sacrifice, financially and bureaucratically. Whereas designating someone a "scientist" on the payroll could work during wartime, a peacetime civil service required more formality. Classification standards did not exist for many technical jobs, in part because the technologies hadn't existed before the war, and it took determination even for the most highly qualified technical personnel to become federal employees. Additionally, salaries for prime positions at universities and industrial companies far exceeded civil service pay levels.[42] By the 1950s, private industry had caught up with government jobs for security and benefits, and the money was better. Inadequate pay was cited as the biggest obstacle to getting the best people to work in defense research and development.[43] As has been amply demonstrated over the decades by succeeding generations of technical personnel employed at the Navy lab on Point Loma, those who remained at NEL shared a passion for their work and a willingness to serve with less attention to personal gain.

Dr. Carl Eckart, who succeeded Harnwell for the last few months of the division's existence, wanted to continue in the academic regime of pure research.

---

[42] Dr. Howard A. Wilcox, Naval Weapons Center interview by Albert B. Christman, March 15, 1978. Wilcox recalled that in his first year of employment at General Motors his income tax bill exceeded his previous year's civil service salary.

[43] Elliott V. Converse, III, *Rearming for the Cold War*. (Washington, D.C.: Office of the Secretary of Defense, 2012).

Commander Roger Revelle, still assigned to the Bureau of Ships, understood and appreciated the significant work UCDWR had done in underwater acoustics and wanted it to continue. He proposed to his bureau chief that he support a University of California research entity, headed by Eckart and sponsored by the Navy.

Captain Rawson Bennett, still heading the Bureau of Ships Electronics Division, but about to be transferred to the Navy laboratory on Point Loma as its director, concurred. Together he and Revelle developed a plan to make that happen. After a substantial amount of persuasion, both of the Navy and of the university, on July 1, 1946, the Marine Physical Laboratory was established, with a staff of five, which included Dr. Eckart as director and later long-time Navy laboratory physicist Dr. Robert W. Young. In late November a contract was put in place, essentially with no termination date and with an extremely broad area of endeavor: "the deep ocean problems of the Navy and the basic understanding of the environment needed for it to operate intelligently."[44]

The small organization was situated in Building 106 at the Navy laboratory waterfront, where it still is (as of 2020), more than seven decades later. Dr. Eckart

Captain Rawson Bennett II (right) and Dr. Carl Eckart plan the post-war working relationship of the Navy Electronics Laboratory and the UC Marine Physical Laboratory.

[44] The preceding paragraph is based on Spiess and Kuperman, "The Marine Physical Laboratory at Scripps."

was MPL director from 1946 until 1952, and for several of those years directed Scripps Institution of Oceanography as well. In April 1948, MPL became an organizational element of Scripps, which itself ultimately became part of the University of California. (See Chapter 9)

The ASW basic research and technology development by the Navy and university labs on both coasts provided substantial contributions to the ultimate successful ending of World War II hostilities. Recognizing the importance of such efforts to their field of interest, the Acoustical Society of America sponsored a retrospective project on the subject in 2015. Ultimately four papers were published by the society, representing work accomplished at the Navy laboratory, the two university war divisions, and the Harvard Underwater Sound Laboratory.[45]

Postwar at NOTS

On August 18, 1945, Captain Sherman Burroughs was, in the Navy phrase, "piped over the side" at China Lake. Over the protests of Caltech rocket program director Dr. Charles Lauritsen and others, Burroughs departed the Naval Ordnance Test Station after being relieved by Captain James Sykes, heading for San Diego to assume command of the escort carrier USS *Cape Gloucester* (CVE-109).[46]

Although Sykes was also a naval aviator (and a submariner), with credible fleet and Bureau of Ordnance experience, his command style differed radically from that of Burroughs, and he was faced with a different set of tasks. Dr. Wallace R. Brode, head of the NOTS Science Department, recalled the first words of Sykes to those assembled for the change of command expressed his belief a research laboratory was like a battleship: going forward, they were to order whatever required brought to the base every six months, and then the desert lab would function self-sufficiently with what it had, as if putting out to sea. No driving back to Pasadena to pick up film or tubes or radio parts or anything else that might be useful. Work would be organized, predictable, and planned. Brode's response: "It is that sort of philosophy which grinds the scientists to a halt very quickly."[47]

---

[45] Acoustical Society of America, *Proceedings of Meetings on Acoustics*, Pittsburgh, Pennsylvania, 18-22 May 2015.
[46] *The Grand Experiment at Inyokern*, 224.
[47] Dr. Wallace R. Brode, interviewed by Albert B. Christman, May 1969, Archives of the

Sykes was not unjustified in his assessment things needed cleaning up. There were organizational inefficiencies throughout the service laboratories which could be overlooked during the press of war, but which in peacetime were not defensible. There was confusion and duplication amid technical improvisation. Turnover among civilian employees at the labs, especially at the spartan China Lake facilities, was high. The urgent need for skilled labor, combined with wartime competition for that labor (and the military taking so many out of the labor force), forced some crews in areas like construction to hire whoever was available.

As discussed in Chapter 4, National Defense Research Committee officials managing the Manhattan Project sought the time and energy and brain power of leaders of the Caltech rocket team and proposed to fill the void by turning over rocket program leadership to the military and civilian personnel (there were few of those) of the Naval Ordnance Test Station.[48] As the war ended, that became the standard plan for all the work previously handled by Caltech personnel.

There was some similarity to conditions in San Diego, as the Navy lab assumed major war-time projects pursued by the UC Division of War Research. The major differences were that NRSL/NEL pre-dated the war and UCDWR, and had its own assigned projects and technical personnel to work them before and during the war. Although the work force, as Captain Hammond had suggested in his *Journal of Applied Physics* article, was fairly small, it had substantial experience, and assumption of UCDWR projects was not a formidable task. Given the sunshine and beach environment of southern California, and the fact Scripps Institution (where many of them had worked previously) was easy driving distance, a number of UC scientists might be expected to transfer to the Navy lab.

It was an entirely different story in the Mojave Desert. There were few NOTS civilian employees, and even fewer of those were technical personnel. The NOTS military personnel who had played reasonable roles in rocket projects during the war would transfer soon, as would their commanding officer. The majority of the technical work on rockets had been done by Caltech employees.[49] Their post-war choices were to remain in a bleak, scorching desert with inadequate housing and recreational facilities and the same Civil Service challenges of red tape and low

---

Navy, Laboratory Center Coordinating Group, 1940s–1990s.

[48] Dr. Frederick Hovde letter to Dr. James B. Conant, chair of NDRC, January 16, 1945.

[49] To provide some idea of the Caltech involvement, *The Grand Experiment at Inyokern* lists, in Appendix B, four pages of Caltech "Scientist and Supervisory Personnel (Winter 1944-1945)," some 260 names with titles.

salaries experienced in San Diego (probably magnified), or to return "home" to Pasadena. There they could enjoy the better paid, more amenable lifestyle at a major university in a sprawling urban area, with recreation and shopping opportunities abounding, and where many of them still owned homes near neighbors they'd known for years, perhaps decades. (Many, perhaps most, Caltech folks hadn't really left Pasadena; they merely "commuted" to the desert to test the weapons they'd designed at Kellogg Laboratory, then drove home.)

It wasn't much of a choice.

Nevertheless, "plans were being formulated for the transfer of CalTech programs to NOTS."[50] The new officer-in-charge of construction ordered the contractors to halt work May 31, 1945, but he lasted in that position only a few months and then construction resumed, most significantly on what would be known as the Michelson Lab, named in honor of Dr. Albert A. Michelson, the first American to receive a Nobel Prize in physics. The laboratory named for him was a large and well-equipped facility for research as well as applied science and engineering, and included such practical facilities as machine shops for rapid prototyping of new devices. When the laboratory was completed in 1948, NOTS was established as much more than a test range for university professor-scientists in Pasadena; its own center of gravity was established apart from the Caltech connection that characterized the wartime laboratory arrangement.

The proximity of the test range to that new laboratory would be a major factor in the station's effectiveness in the coming years, according to Dr. William B. McLean, who arrived shortly before the end of the war:

> The very appealing thing at China Lake, when I first went out there, was the fact that the laboratory was planned to be close to the test range. You could work on your equipment and then take it out and get it tested and come back and work on new elements of the problem.[51]

The experimentalist

As a boy growing up in Southern California in the 1920s, Bill McLean loved fixing things. His mechanically talented parents made sure the child mastered

[50] *The Grand Experiment*, 164.

[51] Naval Weapons Center interview of Dr. William B. McLean conducted by A.B. Christman, July 1975.

myriad skills ranging from knitting to plumbing to automobile repair. Figuring out what wasn't working with a machine, and making it work, occupied his imagination, as did another great love: the sea. He recalled fondly family summers spent at a house at the beach; he loved skiing; he was one of the early adherents of SCUBA diving, inventing his own breathing equipment and wet suits.

McLean spent most of the decade of the 1930s in the physics laboratories of the California Institute of Technology. A protégé of Charles Lauritsen, he had worked with him on development of his half-million-volt Van Der Graaff generator as a Caltech Ph.D. candidate. He completed his degree requirements in 1939. Had he stayed at the institute, Lauritsen surely would have involved him in his rocket work, but a postdoctoral fellowship to the University of Iowa progressed to a position with the Bureau of Standards in Washington, D.C. in 1941. There McLean worked on fuzes, rockets, and other weapons systems, testing them at the Naval Proving Ground at Dahlgren, Virginia.

Early in his career at NOTS, Bill McLean (right) conferred with machinist Woodrow Mecham on fabrication of hardware.

The chief scientist at that proving ground was Dr. L.T.E. Thompson, one of the first ballisticians in the nation[52] and an individual perhaps unrivaled in his understanding of the Navy military-civilian relationship and how it worked (and didn't). After nineteen years at Dahlgren, Thompson had moved to the Norden Company in Indianapolis, where he was tasked with setting up the Naval

[52] *The Grand Experiment*, 158.

Ordnance Plant for the Bureau of Ordnance. During the course of the war, Thompson visited NOTS at least once, and at least once a NOTS official visited him to sound him out on suggestions for methods of operation at the station.

In January 1945 the Bureau of Ordnance modified Norden's contract, specifically to obligate the services of Thompson in "supervising the selection of civilian personnel required to staff the Research and Development organization at the Naval Ordnance Test Station…"[53] The bureau had made clear through a number of decisions, both administrative and financial, that it planned not only to sustain the work at NOTS after the war, but increase it. Dr. L.T.E. Thompson was one of the critical elements in that plan, tasked with finding the technical talent essential to the future of the desert station. (Both the bureau and Thompson realized without formal contract stipulations that he also would assist in developing a viable organizational and operational structure for NOTS.)

With the contract modification in place, Thompson began the difficult process of recruiting top-level scientists and engineers to come to the desert. Early on in that process, he recalled his former associate at the proving ground in Dahlgren, and invited Bill McLean to return to California. An experimentalist at heart, McLean realized the potential of the China Lake test ranges in supporting foundational work on proximity fuzes, fire control systems, and arming mechanisms. He quickly accepted the invitation. Arriving just two months before Japan's surrender, McLean would remain for more than two decades, eventually succeeding Thompson as technical director, and overseeing some of the Navy's most significant projects from air-to-air missiles to torpedo research to development of undersea vehicles.[54] His iconoclastic mind led him to challenge orthodoxy, a temperamental blessing that stimulated him to create breakthrough systems like the Sidewinder missile. His greater contribution might have been neither a weapon nor a technical innovation, but an ability to inspire and bring out the best in two generations of scientists and engineers at NOTS.[55]

---

[53] Change Letter No. 10, Contract Nord-3070, published in *The Grand Experiment*, 157-159.

[54] W.H. Pickering, *William B. McLean, 1914–1976, A Biographical Memoir*. (Washington, D.C.: National Academy of Sciences, 1985)

[55] Pickering, *William B. McLean*, 403.

Planning for the future

More than a year before the somewhat unforeseen end of the war in the Pacific, Dr. E.C. Watson, who administered the Caltech rocket program for the institute, developed a proposal

> that was heartily endorsed by Burroughs, calling for a new weapons laboratory to be built in Pasadena. It was to be built and maintained by the Navy… the research staff of highly competent scientists would work under a civilian director who had a high degree of independence and continuity. The laboratory would take over the rocket and underwater ordnance facilities supporting the CalTech Contract OEMsr-418.[56]

The proposal echoed the thoughts of many (a lot of whom found the disadvantages of the desert beyond consideration in peacetime), that a lab and its test site reasonably could be at different locations a few hours' driving time apart.

Dr. Frederick Hovde of the Office of Scientific Research and Development, who had pushed for NOTS to take over the rocket program so Caltech scientists could concentrate on Project Camel, agreed with the concept, but wanted this new lab to be a branch of NOTS, which he predicted at the time "seems to be the only Naval research center on the Pacific coast likely to be maintained as peacetime Naval facilities."[57] He envisioned it as a liaison office of the desert organization, providing access to academic and industrial entities in the huge Los Angeles area.

Most Caltech personnel favored maintaining the R&D efforts in Pasadena, and a survey requested by Captain Burroughs found very few of them would work at NOTS under a civil service arrangement.[58] Burroughs, however, had little time to consider how to respond appropriately to that, since he was about to move on.

About six weeks after McLean arrived in the desert, the Burroughs-Sykes airfield change of command occurred, and Captain James Sykes began a controversial tour of duty.

One of the captains' turn-over subjects, understandably, was the operation in Pasadena. It also was undergoing turnover, as the OSRD organization in its own final days was shutting down war-specific efforts and assigning those with potential lasting value to appropriate military commands. Thus, as earlier

---

[56] *The Grand Experiment*, 172.
[57] Dr. Frederick Hovde memo to Dr. E.C. Watson, August 30, 1944.
[58] *The Grand Experiment*, 181.

mentioned, it had turned over UCDWR functions in San Diego to Bureau of Ships; in Pasadena the rocket and torpedo development managed by Caltech and the weapons manufacturing functions managed by OSRD were turned over to the Navy Bureau of Ordnance, which in turn handed them off to NOTS management.

Contractor hired to manage Pasadena

As discussed earlier, however, NOTS was not adequately organized or staffed to take on these long-distance obligations. The Bureau of Ordnance provided some breathing room by establishing a contract with General Tire and Rubber Company (GT&R) to manage operations in Pasadena while NOTS management worked on its responsibilities in the desert. Despite that, the NOTS commanding officer still held responsibility for what went on at his satellite activity, which was a major challenge when the contractor running the show there reported not to him but to the Bureau of Ordnance.

GT&R's contract, almost $2.5 million for a year (which proved not to be nearly enough time), involved overseeing two facilities on Green Street housing instrument shops and offices and the plant on Foothill Boulevard where Project Camel had pushed aside years of rocket manufacturing to build bomb components. The Foothill Plant employed almost 500 people in a wide variety of disciplines and employment levels. The unanimous opinion was all these employees would be converted to federal civil service at some unknown future date, but for several years Foothill employees were a varied lot of highly educated scientists and manual laborers, GT&R contractors and newly hired employees, employees of California Institute of Technology who were ready to become civil servants, former Caltech employees who already were.

Jim Jennison, who had participated in the successful effort to make the Mark 13 air-launched torpedo functional, was one of the latter:

> October 1st, 1945, I came into Civil Service as a part of a group that had been working with CalTech [sic]. I can't remember the exact number, but I think it was under 100 people that transferred to the Navy at that time; I was one of the first who came into the original torpedo project…[59]

[59] James H. Jennison, Naval Weapons Center interview conducted by J.D. Gerrard-Gough, 23 October 1975, 1.

Morris Dam, where Jennison had worked on the torpedo, was one of the first facilities OSRD transferred to the Navy Bureau of Ordnance, and it had been assigned an officer-in-charge almost immediately. That officer often chose to report to the bureau directly, rather than through the chain of command (essentially Captain Sykes at Inyokern). Given the circumstances—a huge contractor facility reporting to the bureau, a subordinate officer who sometimes ignored him, facilities undergoing transition (the Green Street buildings that were shared by the local representative of the Office of Naval Research)—it's understandable the "battleship commander" Captain Sykes detected dysfunction in his command.

Pasadenans might have agreed. Jennison, for one, expressed reservations about the standing of the physical plant and employees in the eyes of NOTS headquarters: "We felt that the people at China Lake didn't understand our problems… We often thought that their viewpoint, their attitude was that they shouldn't let us be too successful or we might secede from the union, and we had thoughts of doing that."[60]

Aerial view of Pasadena Annex. Security officers prepare to raise the flag at the start of a new day at the annex, with Mark 13 torpedoes as witnesses.

For one thing, the title Pasadena "Annex" was a source of unhappiness, and would be for some years in the future. Volume 2 of the China Lake history admits it "had for some the unfortunate connotation of 'something tacked on.'"[61]

Jennison noted multiple attempts to designate it the Pasadena Laboratory (which would be its formal title when ties with China Lake were severed, but that was two decades in the future). There was a bit of relief some years later when

[60] Jennison interview, 21.
[61] *The Grand Experiment*, 339.

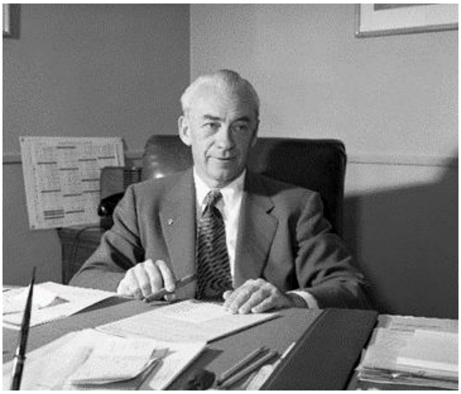
Pasadena officials succeeded in getting one of their buildings named for Dr. L.T.E. Thompson (obviously *after* he had served as research director): "So for a time they would speak of going to Thompson Laboratory rather than the Pasadena Annex. So on an informal basis we made some progress. But officially it was named Pasadena Annex."[62]

Civilian leadership

Thompson, as noted above, had been contracted by the Bureau of Ordnance to recruit technical talent to and assist in the organization of the post-war Naval Ordnance Test Station. Bureau officials, recognizing his leadership abilities, also hoped he would agree to be the NOTS director of research, an opinion shared by many at the station as he visited in his recruiting and organizing efforts. As time went on and Thompson realized the individual in whom he'd placed strong hopes for filling the position was badly needed in a more significant war-support role, he agreed to accept the position, his appointment effective December 4, 1945.

One of his reasons for accepting was the acknowledgement that the positive, progressive tenure of Captain Sherman Burroughs had ended, and his successor would require an adept civilian to move the station into the future. Although Thompson had created an organizational structure early in his contractor period (March 1945), the radical changes and sometimes near hysteria that typified the spring and summer months of 1945 required close scrutiny of the org chart as the new research director embarked on his responsibilities. War-time tasking was ending, and must be replaced by new programs and responsibilities. The large body of Caltech scientists and engineers was slimming down dramatically. Thompson recognized the necessity of a substantially different organizational

[62] Jennison interview, 17-18. The building, incidentally, was the former Vista del Arroyo hotel, a grand hotel once the residence of Howard Hughes that became an Army hospital in 1943, and after the war was turned over to NOTS Pasadena to house offices and laboratories. See: http://www.atlasobscura.com/places/vista-del-arroyo-hotel visited June 5, 2017 and Elizabeth Babcock, *History of the Navy at China Lake, California, Volume 3: Magnificent Mavericks* (China Lake, California: United States Naval Museum of Armament and Technology, 2007), 343.



Dr. L.T.E. "Tommy" Thompson.

structure to meet the challenges of post-war recruitment of qualified personnel, particularly given the spartan surrounding environment of the Mojave Desert.

Stimulated by that concern, he traveled to Washington, meeting with the chief and deputy chief of the Bureau of Ordnance, both old friends. He expressed his conviction that to recruit effectively the caliber of scientists the Office of Scientific Research and Development had employed during the war, he would require what he called a "charter" for that purpose. The two senior officers agreed and asked him to draft one. At the same time, they asked the senior civilian at the Maryland-based Naval Ordnance Laboratory (NOL), another bureau lab, to do the same.

In response, Thompson gathered a small group of associates and together they drafted a document called "Principles of Operations." Unlike NOL's proposed charter, which was very specific and detailed, the NOTS statement was broadly and simply stated.[63] It was fairly obvious, in creating the position of "technical director" and in establishment of various boards with substantial authority, that the document limited some of the important prerogatives of the commanding officer. When Captain Sykes reviewed the document, he responded with what appeared to be a sense of compromise, but suggested the policies remain as such and not be formalized.

Thompson forwarded the "Principles" document to the Bureau of Ordnance chief, who approved it without a single change, but sent it back requesting it also be signed by the commanding officer. Captain Sykes balked at one policy which was intended to provide some substance to the intentionally broad terms of the

[63] Appendix F of *The Grand Experiment* contains the entire two-page document.

“Principles.” The policy at issue was that the technical director, or the Research Board which he chaired, “see all new orders, regulations, and administrative procedures before they were issued by the command.”[64]

(As noted above, the Naval Ordnance Lab had proposed to the Bureau of Ordnance chief a detailed charter which included a new organizational structure. Among other things that structure featured a technical director position with substantial authority and control. NOTS civilian managers were very interested in that concept; the commanding officer was not. He suggested such an organization might be possible at some unknown future date, but not at the moment.[65] The issue of “dual executive” leadership is discussed in more detail in Chapter 14.)

The letter rested on Captain Sykes’ desk for months, unsigned and unforwarded. When Thompson pushed on the matter in November, Sykes responded that the “Principles” had already been approved and the letter was unnecessary to establishing them. He did offer to forward it “with nonconcurrence,” essentially mailing the letter without agreeing to the contents.

Thompson tried again a few days later, with a formal letter advocating his position and another informal one the same day, appealing to the captain’s spirit of cooperation, which was required if the “Principles” were to work. Finally, a week later, Sykes signed the letter and forwarded it.

(Interestingly, on the same day Thompson sought Sykes’s “cooperation,” he wrote a third letter, to his old friend the chief of the Bureau of Ordnance, Rear Admiral George Hussey, requesting his resignation be accepted. The latter regretfully agreed, but Thompson did not follow through. Whether it was the CO’s forwarding of the letter with the amended “Principles,” or some other cause, is not known, but Thompson remained as NOTS civilian leader for another five years.)

To the relief of many, the tour of Captain Sykes as the commanding officer ended November 5, 1947, and did so on an extremely positive note: Not only was his relief, Wendell G. Switzer, an aviator with important Bureau of Ordnance experience, he was also a rear admiral. Nothing spells success more clearly for a military organization than to gain a new officer in command at a higher rank. Compounding that affirmation was this later command title change: the senior officer at NOTS and two other laboratories (White Oak and Dahlgren) in the future would be called “commander,” vice “commanding officer,” another important

[64] *The Grand Experiment*, 262.
[65] See *The Grand Experiment*, 258-59.

distinction in Navy circles.[66] Certainly the most significant fact was that Technical Director Thompson and Rear Admiral Switzer had known each other for years and would be able to work in close cooperation to secure the station's future.

Key to that future was continuing construction on two facilities that would define the organization for decades: the Variable-Angle Launcher and the Michelson Laboratory.

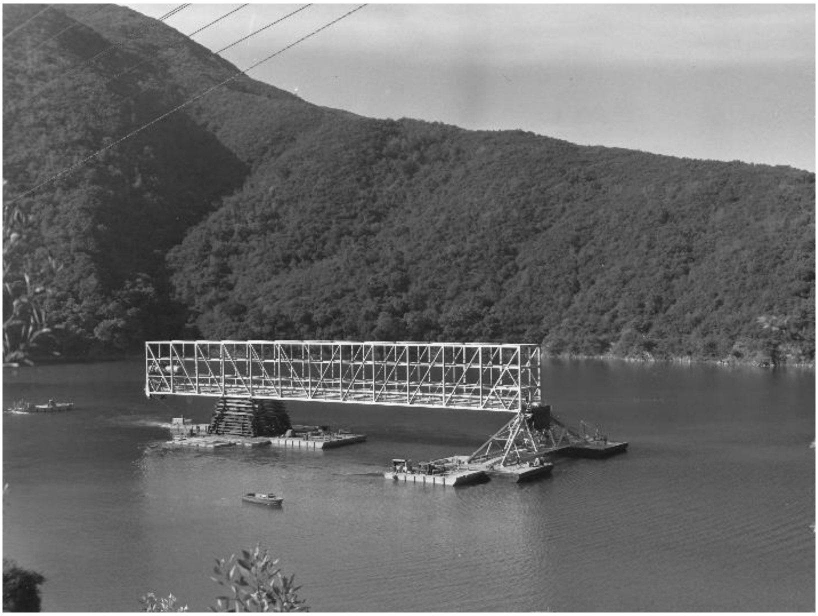
New weapons test launcher

The fixed-angle launcher at Morris Dam, while essential to the improvement of the Mark 13 torpedo, was inadequate for testing new torpedoes that required launches from substantially great altitudes at progressively faster speeds. Design of a state-of-the-art launcher was assigned to Jim Jennison, who previously was a California state bridge builder. In designing the launcher, he basically built a bridge. Termed the Variable-Angle Launcher (VAL), his "bridge" was 300 feet long, 22 feet wide, and 35 feet high, at the time the largest all-welded construction in the U.S. Constructed of steel, almost half of it war surplus, so essentially free, the bridge was built in two sections (connecting bridge and launcher bridge),[67] trucked up the narrow California State Highway 39 through San Gabriel Canyon, and floated across the southwest portion of the reservoir lake to the bottom of the steep-sided peninsula that would provide the "angle" required for the launches.

One end of the launch structure was positioned on two barges floating on the water's surface; on the shore, a rail-mounted carriage supported the other end on a forty-five-degree slope. By moving the onshore end of the bridge up and down the slope, the VAL produced water-entry angles as high as thirty-eight degrees and as low as five degrees from the water's surface.[68] The tremendous weight of the massive steel bridge structure was counter-balanced by a 600-ton concrete and steel car on a thirty-degree slope on the other side of the hill.

---

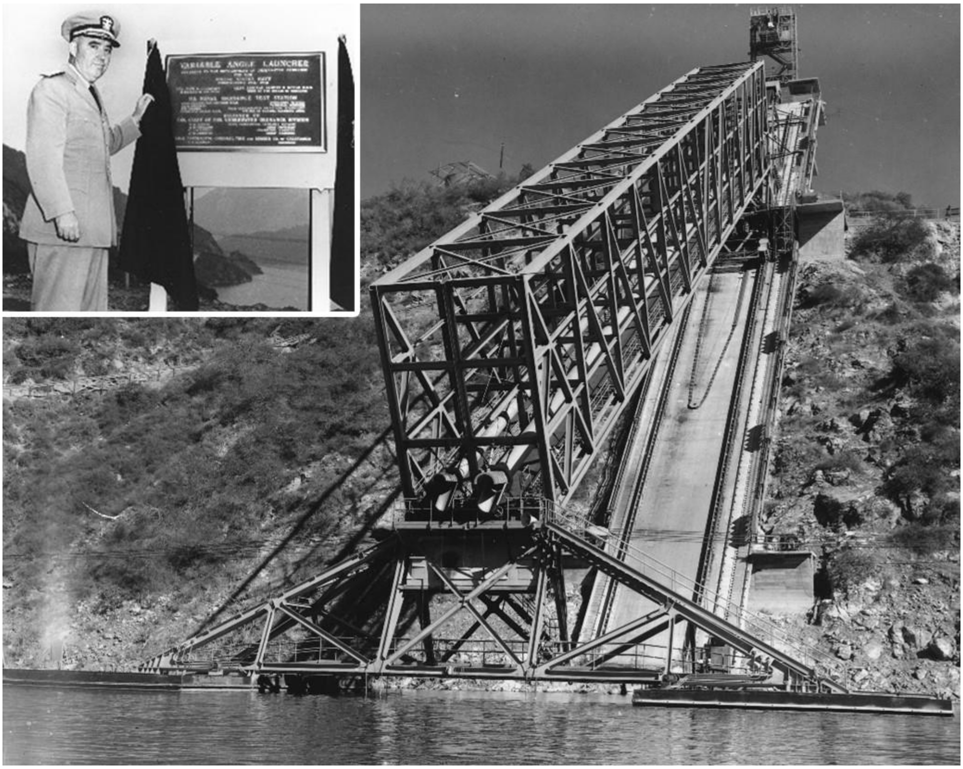
[66] Memo, 1 Nov 1948, "Change in Title of Officer in Command," Executive Officer to All Hands, NOTS.
[67] Jennison interview, 13.
[68] "Morris Dam Ballistic Range," Naval Ordnance Test Station report, July 1964. The following paragraphs are sourced from the same document.



The major component of the Variable Angle Launcher, the launcher bridge, was floated across the Morris Dam reservoir for installation on the steep hill of a peninsula jutting out into the reservoir.

A torpedo-shaped projectile weighing up to four thousand pounds could be launched by the release of compressed air at pressures up to a thousand pounds per square inch, attaining velocities up to two thousand feet per second. Exiting a launching tube of either 22.5-inch or 32-inch diameter, the projectile entered the water into a hydrophone range measuring 1,000 feet long, 150 feet wide, and 140 feet deep. An array of hydrophones along the range measured speed and directional data, and the projectile was recovered for inspection. In addition to the launcher and hydrophone sensors, the designers of the new Morris Dam facility constructed numerous mounts for high-speed cameras around the launcher to record and measure velocity, deceleration, roll, and pitch of the projectile, providing a complete picture of its trajectory. The VAL could in this way reproduce and allow analysis of multiple air-launched torpedo scenarios, from a slow helicopter drop to a high-speed launch from a Navy jet.

The reservoir was also the site of an underwater rail launcher, a pair of rails which could be lowered from a barge to launch projectiles of 10 to 22.5 inches in



Business end of the Variable Angle Launcher. NOTS Commander Rear Admiral Wendell G. Switzer (inset) dedicated the launcher May 7, 1948.

diameter underwater. These projectiles were fired at an impact plate with an adjustable angle between five and ninety degrees from horizontal; such a simulation provided data on torpedo behavior when it struck a submarine hull.

Dedication ceremonies

The first week of May in 1948 was a busy travel week for NOTS leadership. On Friday, May 7, they made a quick visit to the Pasadena Annex, then motored east on Foothill Boulevard to Azusa (along the famous U.S. 66, by the way), then north out of town to San Gabriel Canyon. With a large crowd of Bureau of Ordnance visitors, Dr. Robert Millikan of Caltech, other Navy and some local officials, Rear Admiral Switzer dedicated the VAL facility by launching the second torpedo through the tube. (The first, the day before, was to ensure everything worked; the small disaster of its launching before the firing button was pushed was corrected before the dedication.[69]) Dr. W.V. Houston, president of Rice Institute and a Caltech alumnus, was keynote speaker.[70]

After the ceremony, Rear Admiral Switzer, Dr. Thompson, and their entourage retraced their route to the airport and flew to Inyokern for the Michelson Lab dedication the following day. Much more formal than the Morris Dam event, its hundreds of attendees watched a military color guard parade the colors, heard an invocation, accepted welcome from Rear Admiral Switzer, and listened to an appropriate congratulatory speech from the chief of the Bureau of Ordnance. The honoree's three daughters were in attendance, and one expressed thanks on behalf of all for this significant tribute to their father, Albert Michelson, a naval officer who was the first American scientist to be awarded the Nobel Prize (in physics) and, remarkably, a Naval Academy graduate. Michelson had returned to active service for World War I while in his 60s.[71]

The Honorable John Nicholas Brown, Assistant Secretary of the Navy for Air, delivered one of the major addresses. When he finished, he turned to one side and shook hands with a tall gentleman standing with unconcealed pride on the speakers' platform, Dr. Charles Christian Lauritsen of the California Institute of Technology. He presented the Medal for Merit to Lauritsen, with a citation from President Truman lauding the Caltech professor-turned-rocketeer-turned-atom-bomb-expert for his "exceptionally meritorious" wartime service to the nation.

The keynote speaker, eighty-year-old Dr. Robert Millikan of Caltech, spoke with feeling and strong conviction of the contributions of Albert Michelson to the defense of the country.

And finally, it was the turn of the man who was reasonably the most responsible for the Navy research, development, and test station as it was in 1948.

---

[69] Jennison interview, 18-19.

[70] *The Grand Experiment*, 354.

[71] "Albert A. Michelson—Biographical," Nobelprize.org, accessed January 5, 2015, http://www.nobelprize.org/nobel_prizes/physics/laureates/1907/michelson-bio.html.

China Lake's massive Michelson Lab, named for the first American recipient of the Nobel Prize, was dedicated May 8, 1948, just 24 hours after the dedication of Morris Dam's Variable Angle Launcher.

Dr. L.T.E. Thompson cited past and present accomplishments, did not try to hide the problems, and expressed optimism at the future:

> Possibly the most significant experiment so far conducted at this Station is the one to establish a new type of organization and operation for a research center staffed by a mixed group of civilian scientists, engineers, and naval personnel, operated within the framework of Navy administration…[72]

For the group of civilian and military technical personnel he addressed and commended, the Michelson Lab represented the state-of-the-art for the wide variety of scientific and engineering disciplines practiced at NOTS Inyokern. In six wings, it housed numerous labs to do basic and applied research, and areas designated for development of the critical components of rockets. A large machine shop provided the means of rapidly constructing prototypes. The commemorative booklet handed out to attendees at its dedication stated proudly:

> Michelson Laboratory is regarded as one of the most complete research facilities of its kind in the world. Built at a cost of $7,000,000, it contains more than 9 ½ acres of floor space. The structure is made up of 16 monolithic concrete units, joined in such a way as to prevent possible earthquake damage… the laboratory is air-conditioned throughout. Designed to accommodate a staff of

[72] *The Grand Experiment*, 360.

> about 600, it is equipped for basic and applied research in physics, chemistry, aerophysics, metallurgy and ballistics, and for development work on propulsion, fire-control and guidance systems for rockets and other missiles.[73]

Just seven weeks after the dedication ceremonies, the third year of the initially planned one-year GT&R contract to manage Pasadena ended, and the Pasadena Annex was formally established. On July 1, 1948, some four hundred contract employees were finally sworn in to civil service and the annex moved forward with a formal mission statement: "To plan and conduct a program of research and development in the field of underwater ordnance, including complete torpedo and missile weapons systems for the Fleet."[74]

California Institute of Technology

Following its substantial contributions to the winning of World War II, California Institute of Technology's progress into the future was actually a return to its past: Kellogg again became a physics laboratory where a variety of experiments in the foundational science were pursued by significantly bright students. Eaton Canyon, which had provided a fairly safe area (although one institute man had paid the ultimate sacrifice to the war effort there) to manufacture explosive grains for rockets a reasonably close distance from the Caltech campus, was abandoned as a war-support site, later to become a regional park.

Dr. Charles Lauritsen returned to the classroom and the Kellogg Laboratory, where over the next decade and a half he trained, counseled, and mentored a generation of brilliant scientists. Given his wartime background, he provided sage

---

[73] *Commemorating Michelson Laboratory Dedication, May Seventh and Eighth, Nineteen Forty-Eight*. U.S. Naval Ordnance Test Station, China Lake, California, May 1948. The "earthquake damage" took more than seven decades to occur, but when it did, it was a profound statement of Mother Nature. On July 4 and 5, 2019, temblors of 6.4 and 7.1 magnitude struck the area, followed by more than a year of aftershocks, which severely damaged the laboratory. Despite additional seismic upgrades over the years, which were credited with preventing even greater destruction, "approximately 40% of the facility was unsafe for occupancy after the earthquake due to structural damage," and had to be demolished. Laboratory reconstruction was well underway in mid-2021. July 21, 2021, email from Kimberly Brown of Naval Air Warfare Center Weapons Division China Lake to NIWC Pacific librarian and archivist Kelly McKeever.

[74] NOTS Pasadena Annex Mission Statement, *Station Journal 1959*, Jan-June, 183.

technical advice to the Department of War/Defense and to U.S. policy makers for decades, serving on scores of committees that benefitted from his expertise.

His son, Dr. Thomas Lauritsen, also returned to the classroom, and was reportedly an extremely popular professor among his numerous students. For his war service he was presented the President's Certificate of Merit in 1948 and a Naval Ordnance Award for World War II efforts on rockets, proximity fuzes, and the Project Camel portion of the Manhattan Project. He later performed substantive research on the evolution of the universe and formation of chemical elements; his field was astrophysics.[75]

Dr. Richard Tolman, who had served as Vannevar Bush's deputy and one of his major division heads and then worked as chief scientific advisor to Major General Leslie Groves on the Manhattan Project, was awarded the President's Medal for Merit and the Order of the British Empire. He returned to Pasadena in 1947 and died unexpectedly a year later.[76]

Sarah Hopkins

"Sarah's principal responsibility is providing guidance and liaison in administrative matters between a highly variable task organization of the Arctic Sciences Division and the more conventional fixed organizational structure of NEL," according to the laboratory's newspaper.[77] Sarah Hopkins spent almost half a century working on Point Loma, the vast majority of it at the Arctic Submarine Laboratory. Managed by Dr. Waldo Lyon, it was, as noted, a "highly variable" organization within the more rigid Navy lab environment. Lyon, the Navy's premier Arctic expert, had technical responsibilities that left little time to

[75] http://www.nasonline.org/publications/biographical-memoirs/memoirs-pdfs/lauritsen-thomas.pdf visited May 15, 2017.
[76] http://www.nasonline.org/publications/biographical-memoirs/memoirs-pdfs/tolman-richard.pdf visited May 15, 2017.
[77] [78] NEL *Calendar*, January 20, 1967, 2.

administer his organization. Sarah handled many administrative duties for him, maintaining effective liaison between the small lab and the larger organization, at times a significant challenge.

Arriving on Point Loma in April 1941 as one of the first employees at the University of California Division of War Research, she served as the first telephone operator. The Navy Radio and Sound Laboratory director was so impressed he asked her to join Civil Service and work for him, which she did for the duration of the war. In addition to telephone duties, she was responsible for establishing and maintaining NRSL's central files, including incoming and outgoing mail, registered publications, technical reports, and various other records.

In 1947, she transferred to Waldo Lyon's Special Studies Branch, where, with a plethora of name changes, she spent the next four decades.

Sarah Hopkins in the control room of the Arctic Submarine Laboratory, where she worked for more than four decades.

Her responsibilities were also highly variable, including physical security, personnel, and equipment coordination and transportation. In the latter role she was cited her first year for coordinating procurement, transport, and placement of the radioisotope generator that powered the unattended oceanographic telemetry station on Fairway Rock in the Bering Strait, near the Arctic lab's Cape Prince of Wales, Alaska facility.

She received an outstanding rating for support in 1960 of two icebreaker and two major nuclear submarine expeditions to the Arctic.

Three months after Sarah began her lengthy career on Point Loma, her future husband, radio engineer R.U.F. Hopkins (nicknamed "Hoppy") arrived, initially as a contractor but then becoming an NRSL employee. Meeting based on the formation of a carpool, they married July 11, 1945. He worked at the lab for thirty-seven years and retired. Sarah worked in her ASL admin role until 1987, when she became advisor to the Navy captain who was the director. She passed away in 1988, still working, with forty-seven years of service.

6

Digits and Icebergs

Groundbreaking ceremonies tend to the melodramatic, as some reasonable number of "important officials" line up, ceremonial shovels poised (also more or less in a line), an official foot on each shovel ready to push it into the ground as if they are beginning to dig the foundation of the planned structure, all while wearing suits and ties and hard hats, smiling for the camera. Real or imagined drama aside, groundbreakings are signs of optimism, positive indications some individual or entity is investing substantial sums of money in the belief the resulting structure will be viable for its designed function fifty or eighty or a hundred years from the turning of those ceremonial shovels of dirt.

Thus, on June 24, 1949, when Eleventh Naval District Commandant Rear Admiral Wilder Baker turned over his shovel under the watchful eyes of U.S. Navy Electronics Laboratory Director Captain Rawson Bennett II, there was cause for hope and positive thinking. The catastrophic horror of World War II had ended almost three years earlier. Post-war necessities such as sending home most of the troops and decommissioning most the platforms had been accomplished, and a pair of security-essential atomic bomb tests had been conducted.

During those three dozen months of plummeting military spending, the Navy had made firm decisions counter to the overwhelming trend and announced it would retain its two California laboratories, established just prior to and in the middle of the war to support its communications and weapons requirements. And not only would it retain them, but it would increase their payrolls and their assigned tasking, and, in that mode of optimism, construct new major facilities for both. For the Naval Ordnance Test Station, it was the unique weapons launcher at Morris Dam and the impressive Michelson Lab, dedicated May 7 and 8, 1948. Now, a year later, it was time for major construction to begin at the Navy Radio and Sound Laboratory in San Diego, whose new title of NEL was less than six months old.

Immediately priot to the groundbreaking, there was a decommissioning ceremony half a mile to the south, as the Navy Radio Station Point Loma ended its four-decade service on the point. Ceremony guests included the Navy chief electrician who had established the station in May 1906 and the Navy commander who was in charge of it December 7, 1941. The latter, on duty that day as reports jammed the air waves, had remained at his post for sixty hours, serving during that time as the principal communications link between what remained of the Pacific Fleet at Pearl Harbor and civilian and military leadership in Washington, D.C.

Equipment from the decommissioned radio station was moved to Imperial Beach to provide space for the NEL expansion.

A newspaper account of the NEL groundbreaking ceremony reported the $1,153,000 structure would provide work spaces for 1,100 scientists, engineers, and others to "continue a program of electronic research now conducted largely in former army barracks."[1] It noted construction was scheduled for completion in a year, but additional units would be added if Congress approved funds.

The resulting structure, officially termed the "Laboratory, Supply, and Utilities Building," but commonly referred to as Building 33, ultimately was built in three major phases over the next several years. The first, interestingly enough, was the last numbered—Wings 5 and 6, located at the north end of the building

In ceremonies held in rapid succession several hundred yards apart on June 24, 1949, Navy Radio Station Point Loma was decommissioned, and 11th Naval District Commandant Rear Admiral Wilder Baker, under the pleased gaze of NEL's Captain Rawson Bennett, broke ground for the Laboratory, Supply, and Utilities Building.

[1] Howard O. Welty, "Navy Breaks Ground For New Laboratory," San Diego *Union,* June 25, 1949.

and including spaces for the Supply Department's necessary functions of contracting, purchasing, and shipping and receiving. The first phase was accepted by the Navy in mid-June of 1950. The second phase was the construction of Wings 3 and 4, followed by the south end of the building—Wings 1 and 2—which was completed November 15, 1952. Built on a decided slope, the north end has a basement, first and second floor, while the south end has only a second and third floor. A cafeteria built on the roof was joined many years later by two conference rooms and a large classified vault structure. The original building was dedicated April 24, 1953. It would provide office and laboratory spaces for hundreds of scientists (primarily physicists) and engineers (overwhelmingly electrical and electronic), plus the offices of the laboratory's executives.

Watching the commandant turn over that shovel of dirt to the flash of camera bulbs and the applause of his several hundred employees, Captain Bennett reasonably could anticipate a bright future for his Point Loma Navy laboratory.

The first of three construction increments, completed in a year's time, consisted of Wings 5 and 6 of what would be commonly known as Building 33, the Point Loma lab's headquarters for nearly seven decades.

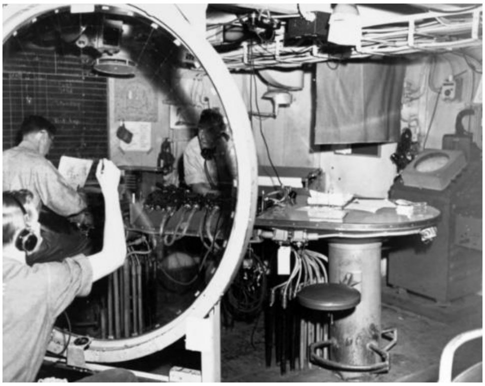
Rawson Bennett had worked very early on with the lab as he was setting up the Fleet Sound School in San Diego, then transferred five months before the start of the war to the Bureau of Ships, where he headed the Electronics Design Division. He not only directed efforts of Navy military and civilian engineers and contractors in developing wave-of-the-future electronic devices, but personally designed sonar-related equipment advancing the ASW effort that was critical early in the war and to the pro-submarine mission near the end of it. After working at long-distance with the Point Loma Navy engineers for five years, he was selected to lead them into the promising future. That future would include a leadership role in the development of one of the Navy's most significant and successful systems.

A new era

The individual in charge of a warfighting platform—a ship's commanding officer, the pilot of an aircraft, the tank commander—faces six critical questions: Who/What is out there, near my position? Where is he? What is he doing? Is he friendly, unfriendly, or neutral? If he's unfriendly, will he take hostile action against me? If so, what should I do about it? In more formalized military jargon, those questions equate to the six critical information challenges relative to the enemy: detection, localization, characterization, classification, threat assessment, and analysis. (The criticality comes, by the way, from the fact that if those questions remain unanswered, there are two likely outcomes: the platform may not be able to perform its designed/desired function, and it may be destroyed soon.)

Over the centuries of warfare at sea, a variety of approaches to gathering, transmitting, and receiving answers to these questions has been developed: look-outs; spyglasses, telescopes, and other sensing devices based on optics or sound; signal flags or lanterns; even carrier pigeons. Of substantial importance in this process is the ability not only to gather the information, but also to convey it in a fashion that a human being in charge can understand and take appropriate action.

By World War II, the U.S. Navy's state-of-the art technology for integrating and displaying this vital command information at sea consisted of grease pencils and a vertical glass panel, on the back side of which sailors would record the location and nature of friendly and opposing forces relative to the ship. They wrote backward so the tactical action officers in front of the panel could read it normally and grasp its significance at a glance. Spotters, pickets, sonar and radar operators radioed or telephoned what information they could discern as aircraft, surface ships, and submarines came to their attention. Action officers assessed the changing situation on the glass panel and responded accordingly.



Sailor on USS *Guadalcanal* (CVE-60) writing combat data backward on glass panel.

Even before the age of jet aircraft, this manual system could be overwhelmed by the chaos attendant upon any sea battle involving multiple combatants, especially when a reasonable number of those are operating in the three-dimensional volume of the air overhead. In the Pacific battle of Okinawa, for example, spotters couldn't distinguish quickly between Japanese fighters, bombers, and kamikaze aircraft, as scores of planes swarmed U.S. ships. Every plane potentially posed a number of different threats, so commanders had to try to recognize patterns of attack and make judgment calls as to the best defense.

Inherent in a stationary display system such as a glass panel is the limitation that it can be viewed only by the crew of one ship; on another ship several miles away, particularly in the confusion of battle, identical information might be interpreted and displayed radically differently by its crew. (And in point of fact, it was most unlikely two ships would have anything resembling "identical" information.) Most difficult was the challenge of the group commanders, faced with the requirement to comprehend several interpretations of the same information on enemy (and their own) platforms and from that information to draw up, often on the fly, appropriate battle plans to maximize damage to the enemy and minimize friendly casualties. Particularly for them, information was incomplete, quick to change, sometimes contradictory, and subject to mistakes.

Dave Washburn, a psychologist and operations research analyst at the Navy Electronics Laboratory assigned to map and document communications aboard ship, described the situation during a fleet exercise:

> They had the different staff functions… during these exercises, and it would consist of a room in which, cheek by jowl, there would be about eight senior officers... One would be acting as the AAW [Anti-Aircraft Warfare] coordinator, one would be surface, one would be ASW [Anti-Submarine Warfare] coordinator… These people were trying to coordinate for the force with just earphones on and runners coming to them with messages that came in on the radio, teletype or telephone or whatever else. They tried to monitor all this and, all the while they had two or three loud-speakers on radio circuits over their heads… split-headset ear phones on. He might have one phone coming into the right ear connected to his 'talker' down in CIC [Combat Information Center], who is looking at the surface plot and telling him what new entries there were; and on the other ear, he'd be listening to the radio circuit with the pilots or with the other ships. It was incredible what they asked these coordinator people to do.[2]

Soon it was no longer just incredible, but impossible. With the introduction of jet aircraft, long range tactical rockets, and advanced submarines, the task of coordinating all this information grew beyond human capability. Blue-water combat in the mid-1950s contained too many variables, too much speed, too many surprises. Psychologist Jeff Grossman, who joined the Navy laboratory system a decade or so later, put it this way: "We can't be writing backwards on blackboards and so forth, because [jets] are too fast. And the Soviets are building too many of them. It can't be done by humans any more. We've got to build these new machines that can handle this!"[3]

Project Lamplight

Rawson Bennett had been relieved as NEL director in July of 1950. After a year's tour setting up a new Department of Defense electronics agency, he was

[2] Dave Washburn, Naval Ocean Systems Center interview conducted by Mark Jacobsen, November 1987, 15-16.

[3] Jeff Grossman, SSC Pacific oral history interview conducted by Tom LaPuzza, August 2, 2012, 26. In this quote he was discussing, and specifically paraphrasing, David Boslaugh's *When Computers Went to Sea: The Digitization of the United States Navy*. Calling it "the best book for this laboratory I have ever read," Grossman suggested all recently hired at the Point Loma lab should be given a copy, followed by "a four-hour colloquium for all new employees around this book." Taking that to heart, the book is cited frequently in this section about the Naval Tactical Data System and related subjects.

assigned to the Bureau of Ships for a brief stint in mine warfare, followed by a naval inspector tour at a contractor facility. In February 1954 he returned to BuShips, this time as the assistant chief for electronics. In this role he had the opportunity to address, and substantially affect, the future electronic Navy. (As will be discussed several times, Bennett in his later positions supported the Point Loma laboratory with problem tasking and funding, and was a frequent visitor.[4])

One promising approach to that future was the multi-service initiative Project Lamplight, directed by managers from the Massachusetts Institute of Technology Lincoln Laboratory. It was an early effort to apply computing power to electronic data such as radar readings. Seeking a credible leader and champion for his service's interests, Bennett reached back to the Navy lab in San Diego for an appropriate candidate to lead the project's Navy portion. He had identified a specific officer who had served under him at NEL and with whom he might have crossed paths earlier during their mutual years at the Bureau of Ships in the mid-1940s. That officer had been at the forefront of World War II radar development and training, and would eventually compile a record of technical achievement very much like that of Stanley Hooper, whom we met in the first chapter. As Hooper contributed vast technological expertise and achievement to satisfy Navy radio requirements, so would Irvin McNally to its radar and information management needs.

Irvin McNally had earned a degree in electrical engineering in 1931, but given the time frame and the country's desperate circumstances, he despaired of getting a job in that field. Although an Army reservist, he took the advice of one of his officers during his six weeks of active duty, and joined the Navy as an enlisted sailor. After basic training he was sent to San Diego for radio school. In light of his academic background and the fact he was a qualified radio operator, he was asked to teach, rather than attend, the course. Intent upon gaining practical knowledge in his field, he sought shipboard duty to train in radio communications at sea. Fortunately assigned to one of the Navy's premier radio ships, USS *Pennsylvania* (BB-38), he gathered substantial knowledge of radio and radar operation during his tour, such that when the first formal radar course for naval officers was established in mid-1941, he was selected as one of the instructors.[5]

---

4 "Rear Admiral Rawson Bennett II," *IRE Transactions on Military Electronics*, 1960, 1, hosted by IEEE.

5 David Boslaugh. *When Computers Went to Sea: The Digitization of the U.S. Navy*. Los Alamitos, California: Institute of Electrical and Electronic Engineers, Inc., 1999, 24-26.

That assignment completed, he was bunking temporarily on *Pennsylvania* in Pearl Harbor with a friend in late 1941, seeking to carry out his orders to establish the Pacific Fleet Radar Maintenance School. Barely escaping death from a direct bomb hit on the battleship at the outset of the December 7 attack, his first efforts were in caring for the wounded. In the days following the attack, his radar expertise was in immediate demand: first to repair a unit on USS *Lexington* (CV-2) and then to get inoperable units back in service on twelve Catalina patrol aircraft.

McNally was commissioned a lieutenant (junior grade) on May 1, 1943, and spot promoted to lieutenant on May 15. Asked by sub crews to design a periscope radar, he did so, and, with direct intervention of the Pacific Fleet Submarine Commander, he was transferred to the Bureau of Ships July 1. Once again, he was spot promoted to lieutenant commander and had as his first assignment getting his sub radar into production. Assigned to head the bureau's Shipboard Search Radar Design Section, he served there for the duration of the war and beyond.

In 1949, detailers thought he should be rotated (after seven years), and since the radar program manager at the Navy Electronics Laboratory was due for rotation, they moved him there, where he would serve under Rawson Bennett:

> At NEL McNally carried with him the nagging conviction that the greatest weakness with radar was not with the radars themselves, but was the lack of a way to allow users to rapidly assimilate, assess, and use the large amounts of information that radar could provide. Now he was in a perfect place to try out some of his ideas… Working with a civilian radar engineer and a technician, Everett E. McCown and R. Glen Nye, the trio developed a special-purpose digital computer for their radar data processing problem. Based on that computer, which they termed Coordinated Display Equipment, the Bureau of Ships awarded a contract for development of an automated plotting and vector computing aid for shipboard fighter direction.[6]

Meanwhile, Rawson Bennett had been transferred and now, in his key position as BuShips assistant chief for electronics, was considering how to further the Navy's interests through the Lamplight Project. He recalled McNally's work under him at NEL and requested he be assigned to the Office of Naval Research as the Navy's lead officer for the project. McNally was once again spot promoted to commander, a rank commensurate with officers of the other services working the project. As the Navy representative, he was tasked with developing high-level concepts for a fleet anti-air warfare (AAW) data-handling system.

Once he arrived and became acquainted with the task, he requested his former

[6] *Computers*, 63 & 65.

NEL associate Everett McCown be assigned to the study team, which was approved. Worried after some five or six months the team was not addressing its responsibilities, McNally approached the group's chair to express his concern. The latter suggested he write up exactly what he wanted for the Navy, saying he would be very open to his recommendations.

The result was

> a system to be built around a much different approach based on his radar data processing work with McCown and Nye at NEL—a concept based on compact digital computers of a radical new design, wedded to radar. He reasoned that transistor technology was the only possible way to condense a full-scale digital computer to shipboard size.[7]

He particularly pushed his belief every ship should have stand-alone AAW capability, and, additionally, all ships of a designated grouping (e.g., a task force) should be able to function as a single entity, thus requiring a force digital data link.

Revolutionary theories proposed

Recognizing he was proposing fairly revolutionary theories requiring higher authority approval, assuming higher authority understood them in the first place, "McNally boiled his ideas down to 15 typewritten pages that were conceptual in tone rather than technically detailed, and he coined the phrase Navy Tactical Data System (NTDS) to describe the concept."[8]

Despite skepticism of some Lamplight team members, the concept was passed to Rawson Bennett, who forwarded it to the Chief of Naval Operations. That office also approved, asking the Bureau of Ships to develop a "Technical and Operational Requirements" document. Bennett transferred McNallyto the bureau under him to handle the assignment. Seeking assistance for the gaps in his technical knowledge, it was recommended Commander Edward C. Svendsen could assist; McNally was pleased because "I taught him radar when he was a brand-new ensign."

---

[7] *Computers*, 118-9. As will be discussed later in this chapter, NEL during this time developed a computer-based simulator of a ship's combat information center for the Naval War College that "occupied three floors of a building in Newport, Rhode Island."

[8] *Computers*, 120. It is common usage that a system specifically designed for and used by the Navy is termed "Navy," whereas one designed for Navy and Marine Corps and/or other entities is termed "Naval." NTDS, even in the reference cited, seems prone to either, at least at the outset. Later it was clearly "Naval."

Although the conventional approach to a new project of this scope and complexity with serious system integration requirements was to establish a prime contractor, "McNally and Svendsen proposed instead that the Navy act as its own prime contractor," with industry support in specific areas of need. "This was a radical military project management concept,"[9] and it loaded substantial technical requirements and decision-making responsibilities on the Navy.

The two obvious choices to deal with those requirements were the Naval Research Laboratory and NEL. While the former was highly experienced in radar technology and managing analog radar data, the lab in San Diego had substantial experience in digital radar data processing. Although perhaps the previous assignment of both McNally and Rawson Bennett to NEL might have played a small role in the decision, what surely prevailed was common sense: the new system would be used by the fleet, but both McNally and Svendsen had experience with fleet rejection of new technology. In fact, in this particular instance, "One informal survey among Navy line officers during the early development phase showed the feeling to be 20 to 1 against the NTDS."[10] Realizing fleet buy-in was critical, and understanding the fleet was in San Diego, they chose the lab there, where there would be ample opportunity to demonstrate the new technology during system development to nearby shipboard personnel. (For all of its more than eight-decade existence, the Point Loma Navy lab was within minutes by surface streets or waterways from one of the two largest concentrations of U.S. Navy ships and submarines in the world, a substantially positive position when the lab's products were almost always intended for use aboard those platforms.)

The cherry on top of the cake was the fact the Combat Information Center school was in San Diego, right across the street from NEL.

Although they were now senior officers, McNally and Svendsen were essentially staff members to the head of the BuShips Electronics Design and Development Division. Their assigned role was merely to recommend concepts and review and coordinate the development work. Neither officer handled that stand-back-and-watch role particularly well. Recognizing "…the project office was staffed by a small group of strong-willed, highly dedicated individuals who were ultimately endowed with authority and responsibility for the program…"[11]

---

[9] *Computers*, 132.
[10] R.W. Graf, "Case Study of the Development of the Naval Tactical Data System," Cambridge, Massachusetts, National Academy of Sciences, 1964, IV-23.
[11] "Case Study of the Development of the Naval Tactical Data System," VII-1.

they pushed ahead with design and development of the new system, pulling the rest of BuShips along with them. Driven by this dynamic duo and less than half a dozen other fairly junior officers, "The coordinating office would evolve to become one of the first military electronic system project offices, if not the first."[12]

General-purpose computer viewed as "catastrophic mistake"

One of the fairly early decisions on which McNally and Svendsen insisted involved the foundation of the emerging system—the computers that would perform the heavy lifting when the new technology was ready for sea:

> A decision not to use special-purpose computers would seem obvious today, but there were many compelling reasons to embrace such machines in late 1955. Other system designers advised them that applying a general-purpose digital computer to a real-time system would be a catastrophic mistake because only a fixed-program machine could keep up in speed with processing demands, but in a 'leap of faith,' Svendsen and McNally specified that the machines must be general-purpose, stored-program computers… History would vindicate their decision many times over.[13]

As system development proceeded, what might have been a disaster occurred: McNally decided to retire from the Navy. Long story short: based on those numerous "spot promotions" he had received over the years, welcomed each time they came, the former Army enlisted soldier turned Navy sailor recognized he was frozen at the O-5 (commander) level. Despite a remarkable record of past technical achievements, a brilliant mind, and a substantially promising future as a technologist, he would never advance a step farther in his naval career. Acknowledging basically a dead end, he retired in June 1956. Quite reasonably, private industry snapped him up immediately. Selected to head Raytheon's Search Radar Lab, he designed and built the AN/SPS-49 radar, which would become a mainstay of the fleet's long-range air surveillance capability for more than three decades.

The potential disaster was averted when Commander Svendsen assumed leadership of the the project coordination office. McNally would be gone and somewhat forgotten (he was not cited in any of the awards and honors following

---

[12] *When Computers Went to Sea*, 135.

[13] *Computers*, 125. In a manuscript review comment, retired laboratory executive director Carmela Keeney stated: "This debate of special-purpose vs. general-purpose continued for decades, into the twenty-first century."

the successful fielding of NTDS, reasonably since he was no longer in uniform to receive them), but system development under Svendsen would proceed reassuringly to its short-fuse end goal.

The Bureau of Ships program management team determined to contract with three companies to develop the critical large building blocks of the NTDS hardware: Remington-Rand UNIVAC (later Sperry-Rand) would be responsible for computers and system development;[14] Hughes Aircraft would develop the displays; and Collins Radio would provide the needed communications. Charles S. "Chuck" Manning, head of the Systems Division at NEL, directed the integration program, at first with a team of two officers and fifteen civilians. The "technical support" of NEL was far more extensive than the phrase might suggest: laboratory staff was responsible for systems management, integration, testing, and training. From an initial 60 engineers and scientists, the team swelled to 130 in 1959, which represented almost a third of the entire technical workforce at the lab.[15]

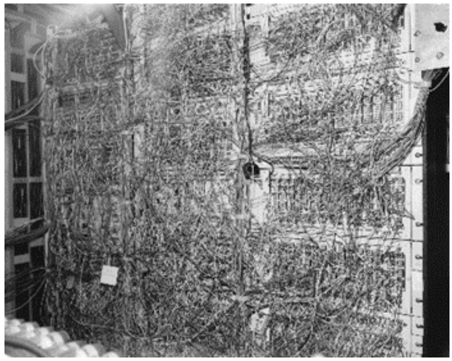
Led by NEL as the system integrator, this combined effort resulted in what came to be known as "the world's first all-digital system." Lab scientists oversaw the system definition from 1955 to 1957. Then as now, system definition resulted in a document detailed enough to define the output of a component for industry contractors and broad enough to avoid specifying exactly how to get the job done. The Navy civilians also worked directly with the contractors. Everett McCown, who had worked closely with Commander McNally on the Lamplight study team at ONR and was an expert in displays, worked with Hughes. Robert P. McManus contributed expertise in communications and interface problems. The team followed a protocol in which "problem numbers" or "tasks" were sent to BuShips for approval and then farmed out to laboratory divisions through NEL's technical director. Often, tasks were discussed among scientists and engineers in San Diego and Washington before the formal protocol kicked in. Ultimately, relationships were strong enough between BuShips' authorities and NEL that approval was often a formality. The final system definition in 1957 was nicknamed the "Blue Book," and was the master NTDS reference for years.[16]

---

[14] At Remington Rand-UNIVAC, Seymour Cray was chosen to lead computer development for NTDS. Cray is widely credited as the "father of supercomputing" and founded his own company in 1972.

[15] Paul W. Cherington, "Case Studies of Titan II and NTDS," *Toward Better Utilization of Scientific and Engineering Talent: A Program for Action*, National Academy of Sciences Committee on Utilization of Scientific And Engineering Manpower, 1964, 122–124.

[16] Graf, "Case Study," IV-17-19.



While contractors developed the major components of the Naval Tactical Data System, NEL set up the NTDS antenna south of Building 33 (left) and established an evaluation-training site in its Applied Systems Development and Evaluation Center (right top). A "behind-the-scenes" look at connections graphically demonstrates system complexity.

As "definition" became "design and development" in the spring of 1958, NEL was assigned billets for nineteen line officers and eighteen enlisted personnel "to operate the NTDS equipment installed in ASDEC, and comprise the NTDS-CIC Team" [17] and the Operational Programmer Team. Over the next many months, the names of a series of officers appeared in the *Station Journal* as NTDS "operational

[17] NEL *Station Journal* entry, 19 May 1958. ASDEC, the Applied Systems Development and Evaluation Center, basically a simulation facility, allowed evaluation of electronic systems and system components.

programmers" reporting for duty. Around Thanksgiving of 1958, the CNO himself, Admiral Arleigh Burke, visited NEL to hear about program progress.[18]

A program as long and complex as NTDS requires continuity in personnel, and NEL's civilians typically stayed with the project for years. In contrast to the Navy's rotation system for officers, the laboratory's civilian scientists and engineers were neither expected to move nor penalized for focusing on one large project for a long time. While making smaller salaries than their counterparts in private industry, NEL's employees showed greater longevity on NTDS than those contractors, providing critical continuity and enabling the project to move forward uninterrupted. A National Academy of Sciences scholar, developing a case study of the program, remarked on the atypical non-rotation of key engineering duty officers assigned to NTDS and the focus and dedication of NEL personnel through what was a program of historic complexity.[19]

System evaluation

Navy protocol for introduction of new technology is detailed and complex. At its simplest, nearing the end of a hardware development cycle, it involves a technical evaluation (TECHEVAL) in which the hardware is put through a rigorous examination of its functioning in the hands of technologists. This is followed by an equally intense examination of its operation in the hands of the fleet people who will use it—the officers and enlisted personnel on the ships or submarines or aircraft where the new gear will provide some added capability to the platform. Operational Evaluation (OPEVAL) is performed under the watchful (and highly trained) eyes of designated Navy testing experts assigned to Operational Test and Evaluation Force (OPTEVFOR), whose mission is "… to ensure that all systems are as effective, suitable, and survivable as possible and convey their capabilities and limitations to the warfighter."[20] Answerable only to the Chief of Naval Operations in order to guarantee impartiality, the force is, and must be, highly objective and critical in its approach to testing new technology.

---

[18] NEL *Station Journal*, 21 November 1958.
[19] Graf, "Case Study," VII, 5-6.
[20] Rear Admiral Stephen Voetsch and Steven Whitehead, "OPTEVFOR: U.S. Navy Operational Test and Evaluation Perspective: Collaboration in an Uncertain Environment*,"* *International Test and Evaluation Association Journal*, 2008, 29: 142.

While that criticality is observed rigorously for replacement of an older gun by a new one, or an outdated steam boiler by an improved model, one can only imagine the intense focus evaluating a technology like NTDS that never existed.

The TECHEVAL/OPEVAL process has a number of subsets to it, and is long and involved since it is intended to approve (or not) equipment on which mission success and perhaps sailors' lives will depend. One significant feature of the process is separation of the two main functions, allowing technology developers (Navy lab, contractor, systems command) an opportunity to correct flaws detected in TECHEVAL before the hardware is put into the hands of its operational users.

In the case of NTDS, the urgency of getting it into the fleet changed that paradigm. While there was marked unhappiness for most Navy personnel with the idea of some "electronic brain" on their ships running things in some unimaginable fashion, the Navy's top brass—Secretary of the Navy John Connally, Chief of Naval Operations Admiral Arleigh Burke, and the Ships and Ordnance bureau chiefs—wanted it, and sooner rather than later.[21] Thus, the determination was made to conduct TECHEVAL and OPEVAL more or less simultaneously. While technical personnel of BuShips, NEL, and the contractors would operate the system during the first half of the evaluation, and the ships' companies of the first NTDS vessels during the second, OPTEVFOR personnel would be on hand throughout the process. Interestingly, the OPTEVFOR commander at the time, Rear Admiral William D. Irvin, had just established a Pacific detachment across the bay from NEL; its first assignment was the OPEVAL of NTDS.

The selected ships were two frigates under construction and the attack carrier USS *Oriskany* (CV-34), a ten-year fleet veteran. On March 30, 1961 she entered San Francisco Naval Shipyard for a major overhaul to include installation of the first NTDS on a carrier.[22] The frigates, USS *King* and USS *Mahan*, were part of the ten-ship build of the *Farragut* class. Initially numbered as DL-10 and 11, they were redesignated DLG-10 and 11 before construction began.

This was obviously a situation fraught with potential disasters for NTDS. Commander Svendsen, typically, got ahead of that by shifting personnel to ensure he had his best people where they would be needed most. That included getting himself transferred to NEL to direct TECHEVAL and sending the officer who had

---

[21] *When Computers Went to Sea*, 243.

[22] James L. Mooney, *Dictionary of American Fighting Ships*, Naval Historical Center, Office of the Chief of Naval Operations, 1959-1981.

For Operational Evaluation (OPEVAL), NEL personnel installed the first version of the Naval Tactical Data System in USS *Oriskany* (CVA-34) and its escorts USS *King* (DLG-10) and USS *Mahan* (DLG-11)

been working it previously off to begin preparation for OPEVAL. Commander Svendsen embarked on TECHEVAL at NEL in mid-1959, using the lab's Applied Systems Development and Evaluation Center, "a shore-based means for conducting dynamic performance evaluations of electronic systems and systems components, including the human elements involved."[23] ASDEC made substantial use of simulators to provide "controllable and repeatable conditions which furnish a reliable evaluation reference."

Although originally conceived as capable of managing a thousand tracks, in practice NTDS handled 250 fast-moving air targets like jet aircraft and missiles at one time, rendering aircraft location, bearing, and speed, and distributing the information to the appropriate screens to inform operators (and their commanders) of the moment-to-moment situation.[24] Inputs as diverse as ship motion and the orientation of other ships in a task force spread out across 300 miles of ocean contributed to the overall picture. In addition to processing all these inputs, NTDS was able to "recommend" countermeasures, assist weapons control systems in acquiring and assigning targets, and exchange information among fleet units.

NEL's key role was cited in a front-page story in the local paper in late summer 1960, following a national news release by the Secretary of the Navy.[25]

[23] Command History, U.S. Navy Electronics Laboratory, 1 June 1940-31 December 1958, OPNAV Report 5850-5, 8.

[24] Captain David L. Boslaugh, USN, Retired, *Building the U.S. Navy's First Seagoing Digital System,* Chapter 3, 2.

[25] Bryant Evans, "Electronic 'Brain' Bared By NEL For Combat Use," San Diego *Union*, August 27, 1960, 1. The reporter had probably never heard the term "system integration" and in saying NTDS was "built" at NEL, he meant that literally. He later cited the three contractors involved, but in a manner suggesting he either didn't understand, or hadn't been advised by the SecNav press release, about the NTDS development methodology.

Near the end of the story, the reporter quoted a telling statement from the release: "NTDS will be as great a step forward in combat direction as the transition from the sail to nuclear plants has been in the field of ship propulsion."

Over the next year, NTDS was installed on *Oriskany*, *King*, and *Mahan*, and OPEVAL proceeded. When the Navy's first nuclear carrier, USS *Enterprise* (CVN-65), was launched in 1961, she carried an NTDS system installed during construction. Through generations of changes, NTDS remained in service and laid the foundation for innovations in command and control in the following decades.

NTDS becomes standard command and control system

NTDS became operational in 1961, was approved for service use in April 1963, and was employed for decades on Navy ships as the standard Navy shipboard command and control system, performing an anti-air warfare tracking function. Over time, it developed into one of the most important programs in the history of the Navy.[26]

The system was more than an extension of capability for the Navy. In a complex marriage of ambition and good timing, the NTDS program advanced computing. During the early system design, Commander McNally learned about the invention of the transistor and immediately brought that revolutionary technology into NTDS specifications. Had the invention come a few years later, early NTDS designs would have relied on vacuum tubes, making them much less capable and less durable, a key concern at sea. The fact NTDS would be needed in combat meant all systems had to be redundant in case one component failed or was destroyed. The descendant technologies of redundancy may be seen now in satellites, cell networks, and data centers. Flexibility, speed, analog-to-digital conversion, modular construction— these and other standard concepts in computing today trace their ancestry to BuShips and NEL technical work, and the work of the contractors who devised NTDS.[27]

And there were interesting side-lights to the program as well; for instance, the radically different technology of NTDS required the Navy to initiate a new enlisted rate: DS, for Data Systems Technician.

---

[26] "Case Studies of Titan II and NTDS," 122–129.
[27] "Case Study of the Development…," II-3–II-5.

NTDS was arguably the world's first fully integrated digital system, but its greatest impact on computing in general might well be the way in which the project was managed. Instead of planning its creation in a linear progression from drawing board to prototype to production, NTDS's systems and subsystems were created in parallel by different contractors, united by the systems engineering discipline of NEL. Managing such complexity to the point at which a system came together at last was a major leap forward. While methods and tools have evolved, NEL's model was essentially how all design and procurement in high-tech military (and most civilian) design would work as the twentieth century drew to a close.[28]

There were several other important results of the NTDS program. In 1962, the Department of Defense faced substantial procurement problems. President John F. Kennedy appointed a commission to study them. Members were to review all large projects of the military services, select the two most successful from each, and perform detailed studies to determine the reason for that success. The two Navy projects thus selected were NTDS, in which NEL played a major systems integration role, and the Polaris fleet ballistic missile system. Major contributions to the latter project, particularly technology development and testing, were provided by the Naval Ordnance Test Station, the other major Navy lab under discussion in this work.[29] (See Chapter 8 for a discussion of Polaris development.)

Several years later, the National Academy of Sciences undertook a case study effort on two major military projects that had demonstrated substantial success in the use of scientific and engineering manpower. The two selected for study were the Air Force TITAN II intercontinental ballistic missile program and the Naval Tactical Data System. The study noted NTDS contractors credited much of the project success to the technical competence of the Bureau of Ships and NEL personnel involved.

---

[28] In that time period, the government would develop a concept titled Lead System Integrator (LSI). It was a recognition that the increasing complexity of technical systems required some entity with extraordinary expertise in integration to ensure all system components worked as intended, and, more importantly, worked together. That entity might be government or private industry. In Volume II we will discuss how reliance on industry-based LSI resulted in unforeseen and costly consequences.

[29] Captain Edmund B. Mahinske letter to D.L. Boslaugh, 5 April 1993.

Software support

Also of interest, both at this time and three decades later, was establishment of a new internal NEL group reporting to the commanding officer and director beginning in 1959:

> The Service Test Programming Group was originally established at the Laboratory with the intent that this Group would form the nucleus of the Fleet Computer Programming Center, Pacific, when that activity was commissioned, and to participate in the development of the Naval Tactical Data System.[30]

The formal commissioning occurred July 1, 1961. Located in San Diego, directly across the street from "the main gate" serving NEL and its successors to the present day, the group wrote software for NTDS computers, particularly as they were called to manage the substantial air traffic requirements of the Vietnam War. The initial two hundred Navy officers, civilian engineers, and program managers for the Pacific organization were transferred from the group at NEL, as was a similar contingent for the Atlantic.[31]

"Fleet Combat Programming Center was commissioned with the primary mission of maintaining and updating NTDS programs," according to in-house newspaper coverage several decades later.[32] As the programs were distributed to fleet ships, programming center civilian personnel and contractors were deployed to perform test and debugging. Alan Olson, who in the future would be a key trainer at Naval Information Warfare Center and its predecessors, was one of them, and it was not the typical programmer tasking, seated in a quiet, air-conditioned lab correcting software code:

> At one point I was flown from ship to ship in the Gulf of Tonkin during real-time combat, including General Quarters, debugging the NTDS USQ-20 computers in CICs [Combat Information Centers] on [USS] *Kitty Hawk* [(CV-63)], [USS] *Constellation* [(CV-64)], and [USS] *Independence* [(CV-62)].[33]

---

[30] Navy Electronics Laboratory Command History 1961, 1.
[31] Tom LaPuzza, "SSC Pacific celebrates 70 years on the Point," SSC Pacific *News Bulletin*, June 2010, 8; also NEL *Calendar* 30 June 1961, 1, and 3 November 1961, 3.
[32] Naval Command, Control and Ocean Surveillance Center RDT&E Division *Outlook*, April 15, 1992, 3.
[33] Email from Alan Olson to Tom LaPuzza June 26, 2018.

In response to a question about significant efforts during that critical and dangerous time, Olson responded that his

> most memorable fix was to the NTDS software interface with the Ship Inertial Navigation System [SINS], which keeps accurate account of the ship's location. It was critical that NTDS had the correct location in order for ship maneuvering in combat with other ships to be very accurate… aircraft returning to the carrier were also using SINS data to locate precisely their landing platform.[34]

On July 1, 1972, the combat programming organization was renamed the Fleet Combat Direction Systems Support Activity, reporting directly to the Chief of Naval Operations, its tasking

> to develop combat direction systems operational programs for aircraft carriers and amphibious ships; command, control and communications systems software; airbome tactical data systems for E-2 aircraft; and naval standard software for standard embedded computer resources.[35]

As will be discussed in Volume II, the organization would develop the software for hundreds of versions of NTDS and subsequent command and control programs, plus play a key role in satellite communication programs, before returning to the Point Loma lab organization as a result of Base Closure and Realignment Commission actions in the early 1990s.

Headlines from the Far North

The summer of 1960 was a momentous time at the Navy laboratory on Point Loma. (It was as well at China Lake and Pasadena; see Chapter 8.) A mere three days before the substantial press coverage of NTDS on August 24, newspaper headlines across the country highlighted the voyage of USS *Seadragon* (SSN-584), the first sub to negotiate the Parry channel through the Canadian archipelago—the famous, or perhaps fabled, "Northwest Passage"—and continue on to the North Pole, the Bering Sea, and Hawaii. Aboard were NEL scientists Dr. Waldo Lyon and Art Roshon, who supported underwater navigation and conducted sonar experiments during the cruise.

It was the latest in a several-year flurry of international headline-making events climaxing more than a decade of exploration under the vast white ice sheet of the far north. Those came in defiance of, or at least in counterpoint to, the official

[34] Email from Alan Olson to Tom LaPuzza January 15, 2020.
[35] *Outlook*, April 15, 1992.

Navy position, which was, "Development of the trans-Arctic submarine remains in the realm of fantasy."[36] While the Navy maintained that position for a number of years, Lyon and the small cadre making up the NEL Submarine Research Facility had balanced that official Navy scoffing with the belief of their leader that such a submarine was reasonably possible. Lyon's actual position was stated in one of his early reports: "The realization of an under-ice submarine is within reach, and is far closer than had been envisioned."[37] During the next decade, the team had demonstrated rather convincingly that the NEL physicist, and not the senior staff in the office of the Chief of Naval Operations, had the true picture.

Lyon, as noted in Chapter 3, had somewhat unexpectedly stumbled over the challenges of cold water to predicted behavior of sound waves underwater. His tasking during the war related to harbor-defense research, which involved frequent studies of underwater acoustics and collaboration with the University of California contractors pursuing those studies. As a result, he had occasionally worked with Canadian scientists in Nanaimo, British Columbia, a fact that would stimulate him to his life's work in the Arctic even before the war ended.

Submarine Research Facility

In the course of harbor defense work, Lyon designed devices to measure bottom currents in harbors, wave heights, and the wakes of surface ships. Such efforts demonstrated forcefully the lack of general scientific knowledge, and especially the Navy's lack of operational knowledge, on the physics of underwater sound. As a result, he wrote a series of letters in the mid-war years advocating the need to study the physics of sound in deep water, and the resultant requirement to develop equipment and facilities to support that study. His first equipment recommendation was for a tank of sufficient size that underwater sound equipment like proposed sonar projectors could be tested at the high pressures of the deep ocean. With approval of the Navy Radio and Sound Lab director, he ordered a tank eleven feet long and five feet in diameter, with a pressure capacity of 1,500 psi. That would allow simulation of conditions to ocean depths as great as 3,000 feet.

---

[36] Arctic and Cold Weather Coordinating Committee, Office of the Chief of Naval Operations, *The Navy Arctic Operations Handbook*, 1949.
[37] W.K. Lyon, "The Polar Submarine and Navigation of the Arctic Ocean," NEL Report 88, 18 November 1948, reissued 21 May 1959, 6.

In remarks decades later he would say, "In 1944 I took the train up to Mare Island, where shipyard personnel designed a pressure tank for us. We never paid a dollar for it. They built it in between repair of ships hit by kamikazes."[38]

Another requirement for the planned study of pro-submarine support measures was an x-ray machine to study those sonar projectors and other equipment while operating in his high-pressure tank. As his list of requirements grew, Lyon formulated a concept for what he called a "Central Sound Laboratory,"[39] where these devices could work in concert to test underwater equipment. He envisioned a formal physics laboratory positioned within the otherwise electronic engineering enclave that was NRSL, to pursue appropriate science-based research: "Spectroscopy was needed for the study of materials, radiography for the study of internal mechanical structures, pressure tanks and hydraulic circuits for observing materials and devices under deep submergence."[40]

He suggested to the NRSL director that such a laboratory would be a national asset that also substantially supported the submarine fleet.[41]

When Mare Island Naval Shipyard delivered his high-pressure tank, Lyon had it installed initially in the original headquarters building, A4. A controlled temperature-pressure chamber was also operating there, but there was limited space in the building for that equipment and none for the desired radiographic equipment, which was massive and bulky. A new lab location was required.

Over several decades, wars and threats of wars and concerns about defense in those wars had resulted in a large number of coastal defense installations on Point Loma—gun batteries of various types, search lights, anti-submarine nets, and sensors.[42] One of those installations, dating from World War I, was an Army mortar emplacement on the northern edge of the NEL Barracks Area, Battery Whistler . Decommissioned in 1943, it promised an appropriate venue for the desired laboratory. (In fact, Dr. Lyon's comment on it was, "Even if an engineer had attempted to design a building especially for the Facility, it is doubtful that he

---

[38] Waldo Lyon remarks at hail and farewell/award banquet in San Diego June 29, 1985.
[39] William M. Leary, *Under Ice.* (College Station, Texas: Texas A&M University Press, 1999), 9.
[40] W.K. Lyon, "NEL Submarine Research Facility," U.S. NEL Report 336, 16 October 1952, 2.
[41] Waldo Lyon letter to Director, Navy Radio and Sound Laboratory, May 1, 1945.
[42] For an exhaustive treatment of those installations, see H.R. Everett, *WWII Harbor Defenses of San Diego*. McLean, Virginia: Coast Defense Study Press Group, 2021.

could have provided a plan as complete or appropriate as that found in this decommissioned battery."[43])

As wartime operations wound down, construction began to transform Battery Whistler into a research laboratory. Over the next several years, a 15,000-pound-capacity bridge crane was installed, as was a super-pressure chamber manufactured from the barrel of one of USS *Alabama*'s (BB-60) twelve-inch guns. Eventually there would be five pressure vessels of various sizes and capacities in the lab, along with a twenty-two-million-electron-volt betatron, an x-ray device to inspect massive pieces of equipment such as sonar projectors.

During a ceremonial and awards banquet some years later, Lyon would state, perhaps only partially in jest, that the betatron was one of the critical factors in relocating the lab away from NRSL's headquarters building: "We couldn't put it in Building 4 because we thought it would have killed anyone in the area, so we decided to take over Battery Whistler and move in there."[44]

An abandoned World War I battery called Whistler provided what Waldo Lyon considered a perfect venue for establishing his Submarine Research Facility.

---

[43] "NEL Submarine Research Facility," 2-3.

[44] Banquet remarks, June 29, 1985.

In the midst of these foundational efforts to establish the underwater physics lab, an invitation arrived at NEL that would, in a very short amount of time, essentially establish the direction of that laboratory for its entire half-century of operation: officials involved in the planning of Admiral Richard Byrd's expedition to Antarctica invited NEL to participate. Waldo Lyon's suggestion to study the physics of sea ice using a submarine was forwarded and accepted, and he boarded the provided boat, USS *Sennet* (SS-408), on the last day of 1946.

After three days in the ice field and three weeks on the edge of the ice pack conducting experiments with the famed University of California Division of War Research QLA sonar and an NEL echo-ranging sonar, Lyon formed the concept that focused the efforts of his research laboratory, and his life, for decades to come: that the U.S. Navy develop the capability to operate its submarines under the polar ice canopy. (Since the large underlying land mass of the South Pole effectively prevented that, his concept was geared to the Arctic and undoubtedly included the potential for extreme competition with the Soviet Union, which immediately after World War II occupied large tracts of northeastern Europe and could hardly be expected not to seek domination of the seas surrounding those tracts.)

Lyon was fortunate to connect with Rear Admiral Allan McCann, who commanded the Pacific Submarine Force and who had sufficient interest that he not only agreed to provide five submarines for Lyon's early endeavors on under-ice operation, but personally participated in some of the first submarine voyages to pursue that.

Operating from USS *Boarfish* (SS-327), Lyon and Arthur Roshon, one of the principal QLA developers who transferred to NRSL/NEL from the closing University of California Division of War Research, set out in August 1947 for the Chukchi Sea. (Strategically located, the sea washes both the northwest coast of Alaska and northeast coast of Russia, immediately north of the Bering Strait.) *Boarfish* led a small squad of four other submarines and the submarine tender USS *Nereus* (AS-17). The sub was already equipped with a QLA sonar, but was also modified to carry an upward-facing fathometer, the first time that had been done, in order to provide an accurate measurement of the distance to the underside of the sea ice canopy. Aboard the tender, Eugene LaFond, head of the oceanographic section in Lyon's division, directed a group in recording pertinent Arctic conditions, such as sea temperature, salinity, marine life, and bottom contours.[45]

[45] *The Reminiscences of Dr. Waldo K. Lyon*, 34.

First voyage under the ice

Important to their first ventures under the ice was the fact the Chukchi Sea floor was flat and shallow, with known depths that allowed a margin of safety under *Boarfish*'s keel.[46]

With the submarine proceeding cautiously at two to three knots, Art Roshon operated the QLA sonar from the conning tower, while Lyon worked the fathometer in the forward torpedo room, the only spaces available for the equipment. The sub's commanding officer and Rear Admiral McCann spent considerable time on an internal phone system, or running back and forth between stations, comparing readings and interpreting data. The QLA sonar proved highly effective at identifying ice keels. Lyon recalled, "The sonar would tell you by the sound of the echo coming back and what it looked like on the screen [enabling us to] judge, 'that piece looks like a big hunk, avoid that, and go someplace else where the sea looks pretty clear.'"[47]

By cautious, meticulous effort, the NEL scientists learned much about use of the electronic equipment underwater and under ice, and the submarine crew learned at least as much about navigating their football-field-length boat in that environment. After the expedition, Rear Admiral McCann asked Lyon to provide him a plan for future work in this area, clearly planning to continue his support. Lyon responded in March 1948 with a position paper highlighting three objectives:

> 1) development of a narrow-beam QLA sonar for use in identifying ice lakes; 2) study of sound propagation in water of upward refraction and extremely positive thermal layers; 3) oceanographic studies of Arctic areas for topography, thermal-salinity structure, horizontal currents, and the properties of sea ice.[48]

The following summer, Lyon and his team sailed in USS *Carp* (SS-338) with a new objective: to travel under ice without returning to the open sea to surface and recharge batteries. This meant using sonar and fathometers to identify open water within the polar cap. En route from southern California to the northern ice fields, the *Carp* crew practiced vertical ascent.[49] To surface while traveling on an incline,

---

[46] "We did have information on that, and it was extremely flat. It's the flattest area there is in the world." Lyon, *Reminiscences*, 36.

[47] *Reminiscences*, 37.

[48] Leary, *Under Ice*, 24.

[49] *Reminiscences*, 45-46.

as was standard, risked striking ice on any side of the hull, and an area of open water surrounded by sea ice—called a *polynya*—was often too small or irregular in shape for the maneuver. Vertical ascent, by contrast, could be accomplished in a *polynya* marginally larger than the boat, but it was a tricky maneuver, requiring coming to a full stop and surfacing straight up with continuous trimming of the boat.

Carp traveled fifty miles under the ice, surfacing successfully several times to manage the requirement to charge the batteries, "… and we knew then that we could now navigate under—that is pilot, I should say—we could pilot ourselves underneath the ice cover with the sonar and that we could find the open spaces… make a stationary ascent, surface in the water, and submerge again."[50]

Lyon returned to San Diego with high hopes for additional Arctic submarine voyages.

At the same time, Lyon was at a personal crossroads. He had left UCLA as a staff member with the approach of World War II. The understanding was that he would return to the classroom after the war to teach physics, and he did in fact do that for the fall semester 1948 and the spring semester 1949, teaching two days a week and working at NEL the other three.[51] It was an unusual opportunity to experience both life courses immediately open to him, and he determined the life of a college professor was less exciting than "running off in an Arctic submarine." He resigned from his UCLA position. That wasn't the end of the story, however.

Managing the NEL Surface and Subsurface Division with a staff of 150 scientists, engineers, and support personnel was a full-time job, essentially killing any opportunity to do the Arctic-related science that beckoned so enticingly. In 1949, he resigned his division head duties in favor of managing the Special Studies Branch of twelve to fifteen primarily technical personnel who had worked previously with him on Arctic research. Although the term "Submarine Research Facility" appears as the title of the report cited several pages earlier, Lyon says pointedly they didn't mention Arctic submarine work or "we'd have been out of business right away because it was not recognized that there was any need anywhere in the Navy to have such an organization."[52]

Consistent with the official CNO position, Rear Admiral McCann's successor

---

[50] *Reminiscences*, 47-48.
[51] *Reminiscences*, 55-56.
[52] *Reminiscences*, 57.

at Submarine Force Pacific had honored his promise to support the *Carp* expedition, but turned down all subsequent requests for the use of a fleet submarine to continue and expand on the Arctic work. Fortunately, shortly after the war, the Navy Department had turned the excess submarine USS *Baya* (SS-318) over to the NEL in San Diego to continue its efforts (initiated in concert with the UC Division of War Research during World War II) to develop sonar technology. If the Navy refused to provide a sub to support the NEL Arctic study program, NEL would use its own. Lab Director and Commanding Officer Captain Rawson Bennett assigned the submarine and crew to the direction of Dr. Lyon, with the patrol craft EPCE(R)-857 to provide surface support and conduct oceanographic research.[53]

The two vessels departed San Diego in July 1949 to study low frequency acoustic propagation and sound transmission loss in shallow water in the Bering and Chukchi seas. Joining them were the Canadian scientists with whom Lyon had worked on harbor defense during World War II and HMCS *Cedarwood*, a Canadian oceanographic research vessel. The cruise report noted recording of surface-to-bottom temperatures every half hour by *Baya* and every hour by the patrol craft using a bathythermograph. Sonar studies of the temperature-layered waters revealed presence of positive thermal layers near the ice, which would be key factors related to submarine operations in those seas. Lyon confirmed in an interview some years later there was no intent to dive under the ice with *Baya*.

Downtime used for facility upgrades

Baya was assigned shortly thereafter to carry the Long-Range Active Detection (LORAD) sonar, discussed below, leaving Lyon and his associates without a submarine to ride to the ice fields for several years. Icebreaker cruises in the early 1950s allowed some scientific experimentation and data collection related to acoustic propagation in cold water and for sea-ice physics, but they were

[53] Originally planned as an unnamed Patrol Craft Escort near the end of World War II, the boat received another letter—R for Rescue—before commissioning in 1945. An additional letter—E for Experimental—was added after the war. In February 1950, shortly after the cruise with *Baya* to the Arctic, the EPCE(R)-857 was officially named USS *Marysville*.

USS *Marysville* (at the time designated only by her hull number) was assigned to the UC Division of War Research during the war and to the Point Loma Navy lab shortly after it ended. It provided surface support and data collection for scientific cruises with other surface and sub-surface craft assigned to the lab.

less satisfying and productive than submarine operations. The group spent that downtime planning the layout of the lab in Battery Whistler and collecting material where they could find it, gathering small pockets of funding left over from other projects (still defined as "problems") at the end of several fiscal years. In 1956, when the budget squeeze became pronounced, the crew "became steelworkers and started the actual construction of the pool… we had a few welders, and we learned how to lay out steel and drive rivets and all kinds of things."[54] By early 1957, a "fair amount of the construction" of the lab had been completed.

At the time, a new Commander, Submarine Force Pacific (SUBPAC) had been installed and pushed the Bureau of Ships for a solution to a long-term recurrent problem for his boats operating in the far north Pacific: the icing of their snorkel head valves, a complaint echoed by the Atlantic submarine force shortly

[54] *Reminiscences*, 245.

thereafter.[55] The timing was perfect. Lyon suggested his staff could solve the problem if their laboratory pool was completed. The submarine component of BuShips responded by skimming small amounts of money from the funding for four submarines under construction. ("I remember one was [USS] *Scorpion* [(SSN-589)] and one was [USS] *Thresher* [(SSN-593)], because they were both later lost and we've always been indebted for those funds for the completing of the pool," Lyon commented.[56]) Funds previously unavailable for a facility with a vague general concept of testing unknown equipment were provided quickly when that same facility could satisfy an immediate operational requirement.

Supported by the acquired funds, professional welders, ship fitters, and metal workers from the Navy Repair Facility at the San Diego Naval Station were brought in to finish the job, and by the end of 1958 the Arctic pool was completed and ready to operate. In a very short amount of time, NEL personnel determined the cause of the snorkel freezing (and likewise determined the proposed fleet solution exacerbated the problem) and provided SUBPAC an easily workable and inexpensive solution to the problem. Almost as soon as it was completed, the Arctic pool had demonstrated its potential value to the submarine force.

Several years earlier, Lyon had described in a report the pool he was seeking to create to benefit the Navy's ability to operate in extreme cold weather, "… essentially a refrigerated laboratory pool 30 ft wide by 75 ft long by 16 ft deep. A watertight space that can be accessed from outside the pool wall is built into the floor of the pool for observation."[57]

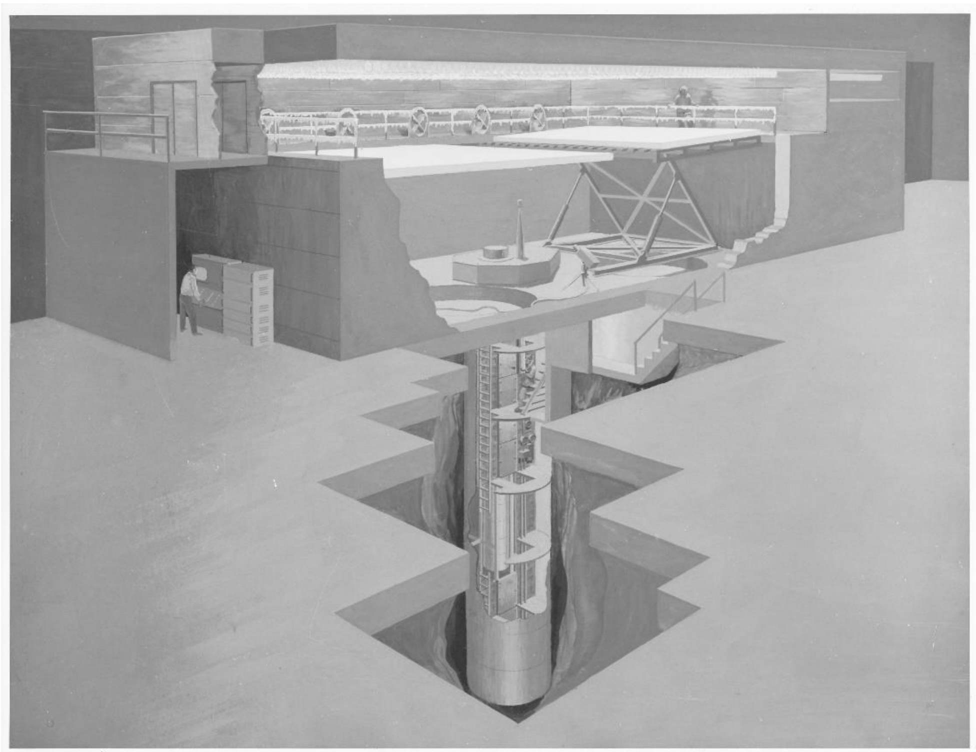
An intriguing side story on that concept: Known to lab employees, few others were aware of it until half a century later, when the lab was being torn down. Workmen involved in that process in the fall of 2002 came across, in the mess of fifty years of operation and five years standing unused, a lengthy cylinder, which turned out upon investigation to be the periscope of the German sub *U-505*, captured by the U.S. Navy June 4, 1944. The sub had been on display at the Chicago Museum of Science and Industry for years. Somehow Waldo Lyon had managed to "appropriate" its periscope shortly after the capture and install it in the floor of the experimental pool, employing it for those underwater observations.[58] It

---

[55] *Under Ice*, 96-97.
[56] *Reminiscences*, 246.
[57] "NEL Submarine Research Facility," 17.
[58] Tom LaPuzza, "Small San Diego Lab Makes a Big Difference," *Mains'l Haul*, Vol. 50: 3&4, Summer/Fall 2014, 63.

was perhaps poetic justice that Lyon, who had spent time during World War II studying the operation of German submarines in cold water, took advantage of the periscope of one afterward to advance his Arctic submarine work.

The Submarine Research Facility's experimental pool held approximately a quarter-million gallons of seawater and could be refrigerated to minus 40 degrees Fahrenheit, producing ice as thick as five feet.[59] Filled with seawater from the nearby Pacific, the pool could effectively simulate Arctic Ocean conditions year-round, for numerous experiments on the effects of salinity, pressure, ice formation, and more. In addition to the various pressure vessels and the betatron, the lab also



Artist's concept of the Submarine Research Facility experimental pool, with its below- ground observation chamber that employed a periscope from a captured German sub.

[59] *Reminiscences,* 247–256. Also, April 1990 official brochure, "Think Arctic, Think NOSC San Diego," 2.

boasted a sea-ice cryostat, in which ship models could be towed through accurately modeled sea ice, providing data on how new icebreakers might be designed.

Canopy underside "ice jungle"

The capability to grow sea ice in the lab demonstrated not only what little was known, but also the extent of what lab personnel *didn't* know. It would take many years to close that knowledge gap. Writing in hindsight four decades later, in almost poetic fashion, Lyon explained the findings of lab studies and observations and submarine piloting under the ice:

> Unlike fresh-water ice, the underside of sea ice is a crushable composite of crystals and brine cells—a low-strength variable layer. To be meaningful to submarine engineering, measurements and physical studies must be made from underneath the ice. [The sea-ice canopy is] highly variable. Viewed from below, it is upside-down, rolling hills of ice; 'badlands' of ice buttes and blocks, scattered or piled one on another; canyons between massive ridges; flat ice planes, and open cracks and lakes… an ice-jungle.[60]

Studying that ice jungle had to be put aside for a while, since SUBPAC refused all submarine requests and *Baya* was otherwise engaged. That left a few cruises on the icebreaker USS *Burton Island* (AGB-1),[61] which included continuing collaboration with the Canadians. That collaboration led to another important Lyon achievement: establishment of a field station for collecting Arctic environmental data and simultaneously adding to the knowledge base required to operate submarines there. Of particular scientific and operational interest was the strategically critical Bering Strait linking the Bering and Chukchi seas.

The plan called for Canadian scientists collaborating with their American counterparts to test a British-developed electromagnetic procedure; if it worked, Lyon's crew would lay a cable at the bottom of the strait, equipped with electrodes to record fluctuations in the local electromagnetic field. That, with temperature readings, would provide valuable data on the temperature, direction, and strength

---

[60] W.K. Lyon, "Submarine Combat in the Ice," *U.S. Naval Institute Proceedings*, 118 (2), (1992), 38.

[61] U.S. Coast Guard website: http://www.uscg.mil/history/webcutters/Burton_Island_1966.asp, accessed March 10, 2015. *Burton Island* had several designations through its service with the Navy and Coast service described here.

of ocean waters passing through the narrow body of water separating the easternmost point of the Soviet landmass from the westernmost point of Alaska.

Lyon found an ideal site, Cape Prince of Wales, where the Civil Aeronautics Administration had operated a Simultaneous Broadcast Radio Range with five 135-foot-tall towers during World War II, a low-frequency range designed to guide aircraft bound for the Soviet Union.[62] (Coincidentally, or not, the station was on the closest American soil to the USSR.) The range had been abandoned, but the weather bureau still had an observation station there, adjacent to the nearby Native American village of Wales. Range facilities, which the CAA turned over for NEL's field station, consisted of two 800-plus-square-foot prefabricated houses, one for the resident manager and the other for visitors; an instrument generator building; a garage; and a storage shed.

Two members of Lyon's division, Gene Bloom and Rex Rowray, played significant roles in the very early days of the facility, with Bloom setting up and conducting much of the scientific research and Rowray serving as the first of a long line of "resident observers" beginning in January 1952. The tasking of these observers, who over time would bring along wives and even in one case a newborn baby,[63] was to maintain the equipment, much of which automatically recorded environmental data, and take what measurements could not be handled by a machine. Bloom wrote the first report on the facility, describing the station's purpose and facilities there, plus the various data collection efforts.[64] He also provided recommendations that included the obvious one of operating the field station on a continuing basis, plus using the electromagnetic method for studying the movement of water through the strait, recording water height measurements, and making use of the abandoned range's five towers to investigate radio wave propagation peculiar to the Arctic.

With the field station progressing through its first year of operation, Lyon was pleasantly surprised to learn he would have a submarine for the Joint Canadian-U.S. Beaufort Sea Expedition of 1952—USS *Redfish* (SS-395). There had been a change of command at Commander, Submarine Force Pacific, and the new officer in charge, Rear Admiral Charles B. Momsen, was a clear proponent of submarine

---

[62] *Under Ice*, 30.
[63] NEL *Calendar*, 4 August 1961, 2, reported on Fred Ulloa, wife Marjorie, and son Mark, who arrived barely a year old and left after two years at the ripe old age of three.
[64] G.L. Bloom, "Facilities and Measurement Program at Wales, Alaska," NEL Report 445, 20 May 1954.

operations in the Arctic.[65] (Momsen had arrived at SUBPAC at the end of a long and distinguished career in the Navy that included commanding his first sub only eighteen months out of submarine school, inventing the Momsen lung to rescue crewmembers trapped in a downed sub on the ocean floor, and directing the rescue of the surviving crewmembers of USS *Squalus* [SS-192], which sank off the New Hampshire coast in 1939. See Chapter 12 for details.)

Lyon used the combination of *Redfish* with the icebreaker USCGC *Burton Island* (WAGB-283) to conduct a series of sonar experiments in the Beaufort Sea, with the surface ship attempting to detect the sub as it moved slowly among ice keels. At the end of those experiments (during which the submarine operated close to the icebreaker, including directly under it, without detection[66]), *Redfish* held her position surfaced in the ice cover, while *Burton Island* steamed away. The two ships continued to perform sonar experiments independently for a week as *Redfish* drifted with the ice. At the end of the week, with no airplane or icebreaker assisting, the submarine submerged and navigated using sonar, fathometers, and charts. For two days, Lyon's team directed the crew to *polynyas* where they could surface and recharge batteries, and finally they reached open water in the Beaufort Sea and rendezvoused with *Burton Island*. The mission proved that submarines could work independently under ice.[67]

The icebreaker's captain reported,

> The results of the experimental work force the conclusion that the under-ice submarine is practical and that its combat potential is great. It is apparently immune from detection or attack by surface vessels operating in the ice, and is capable of detecting such vessels at great distances and attacking them at will.[68]

The report of that cruise seemed to have had little impact on the Navy's negative position on the Arctic, and there were similar reactions (or rather non-

---

[65] Lyon describes in his oral history (Page 66) the ingenious strategy taken by Momsen: he was assigned to the submarine desk in the Office of the Chief of Naval Operations. In that role of authority, he directed the Commander, Submarine Force Pacific to take appropriate actions to support a submarine cruise/availability to the Arctic for the summer of 1952. He was then relieved of his position at OPNAV and reported to his new assignment—as Commander Submarine Force Pacific, whereupon he received his own order to support the submarine operation, and promptly complied by providing *Redfish*.
[66] *Reminiscences*, 73.
[67] *Reminiscences*, 68-70.
[68] *Under Ice*, 61.

reactions) to a small number of icebreaker cruises[69] with the Canadians and with scientists from the Office of Naval Research, Scripps Institution of Oceanography, and the hydrographic offices of the U.S. and Canada, almost exclusively for pure scientific research.[70] With the exception of those efforts, there was little progress over the next half dozen years toward Lyon's goal of Arctic submarine capability. That was about to change.

Submarines go nuclear

"Only about a dozen people—President Eisenhower, the CNO [Chief of Naval Operations], a few others—knew about it," Waldo Lyon advised in an interview on the occasion of his retirement.[71] The closely guarded secret involved a submarine steaming over the North American continent, submerged, from one major ocean to the other, under the polar ice cap. A voyage of such magnitude was for all practical purposes impossible for a submarine required to surface at various intervals to recharge its batteries. Fortunately, there was now a viable alternative.

On September 30, 1954, USS *Nautilus* (SSN-571) became the U. S. Navy's first commissioned nuclear-powered ship. In the following years, she demonstrated the superiority of the nuclear submarine to its conventional predecessor time and again, surpassing all submerged speed and distance records.[72] The latter was particularly important, since it meant the sub could travel the entire width of North America without surfacing once.

Nautilus's first commanding officer was Navy Commander Eugene P. Wilkinson, who had a strong nonstandard-Navy interest in operating his boat in the Arctic. After two years of directing the sub through various early-service

---

[69] Western Electric Corporation, 1960. Reprinted in P. Whitney Lackenbauer, Matthew J. Farish, and Jennifer Arthur-Lackenbauer, "The Distant Early Warning (DEW) Line: A Bibliography and Documentary Resource List," Arctic Institute of North America, October 2005, 14. The icebreaker cruises ended when the ships, both American and Canadian, were required to break paths through the ice for freighters carrying the massive loads of radar equipment to construct the DEW line.

[70] *Reminiscences*, 59-63.

[71] Tom LaPuzza, "Arctic Lab pioneer Dr. Waldo Lyon retires after 55 years," Naval Command, Control and Ocean Surveillance Center RDT&E Division *Outlook*, 1 November 1996, 3.

[72] "History of the USS Nautilus," USS Nautilus Museum website: http://www.ussnautilus.org/nautilus/index.shtml, accessed March 10, 2015.

NEL's Dr. Waldo Lyon seen at left on the deck of USS *Nautilus* (SSN-571) with "father of the nuclear Navy" Rear Admiral Hyman Rickover, and aboard the sub watching sonar returns with Commander William R. Anderson, the boat's commanding officer.

operations, Wilkinson proposed steaming under Arctic ice for five hundred miles near Spitsbergen, east of Greenland, and near deep areas of the Arctic Ocean.[73] Upon hearing the proposal, Waldo Lyon appealed to his previous commanding officer, Rawson Bennett, now a flag officer and Chief of Naval Research, to support a longer voyage. With tacit support from the Chief of Naval Operations (CNO) and an influential U.S. senator, and specific assistance from a naval officer friend from the USS *Redfish* expedition who was now assigned to the CNO's submarine desk, Lyon prepared an alternate proposal for a submerged transit of the entire Arctic Ocean. The work of Lyon's lab on the snorkel de-icing problem and some submarine hull research lent credibility to his ideas, and by July 1957, Lyon had the approval he sought.[74]

With a new commanding officer, Commander William R. Anderson, *Nautilus* steamed north and east from New London, Connecticut, in late summer 1957 with Lyon aboard, with the intent of an Atlantic-to-Pacific crossing of the Arctic Ocean. Installed on the submarine were several upward-facing fathometers from earlier trips under the ice with conventional subs. Although the North Pole was not specified as a goal, Anderson had been granted permission to use his judgment on the extent of an under-ice trip. Equipment failures and a mishap while surfacing in a *polynya* (ice damage to both periscopes) forced the submarine to

---

[73] *Under Ice*, 93.
[74] *Under Ice*, 91-99.

return to New London after reaching a latitude of 87 degrees North, less than 200 miles from the pole.[75]

Mission supporters planning a second attempt the following year received an unexpected boost in October when the Soviet Union put the first artificial satellite, *Sputnik,* into Earth orbit. American officials and the public, shocked at the Soviet display of technological expertise, clamored for demonstrations of scientific leadership and pride, but were first greeted with disaster: on December 6, 1957, the first American satellite launch attempt, Project Vanguard, exploded on the launch pad in front of a global television audience.

On February 17, 1958, the top echelon of the Navy (with White House backing) approved Operation Sunshine, a transit from the Pacific to the Atlantic underwater, under ice, and under the pole. The scientific and military considerations of Waldo Lyon and the *Nautilus* skippers aside, there were two significant aspects to such a feat. The national and public desire for a comparable achievement to *Sputnik* would certainly be satisfied, but, more importantly, demonstrating to the world the U.S. Navy could operate undetected anywhere in the Arctic—meaning anywhere along the vast northern coastline of Russia—added political value to the mission and on its own was reason enough to go.

The change in direction mandated by the Navy Department was to increase the potential for a successful mission. Although the original attempt to transit the Arctic Ocean was planned as east to west, the fact water conditions were more promising—problematic shallow water in the west could be dealt with at the start of the voyage, and, once overcome, the submarine would enter deeper, safer water as the journey progressed—suggested west to east was preferable, to avoid failure at voyage end due to ice blocking shallower water.[76] Interestingly, the World War II QLA sonar, developed by the UC Division of War Research on Point Loma specifically for transiting mine fields, had been employed very effectively with the early under-ice boats in detecting and characterizing ice hazards to navigation. Since post-WWII boats like *Nautilus* had no mission to transit mine fields, the sonars had been removed.[77] Lyon would lament not having one, but stated several times that requesting one would have divulged the highly secret mission.

Nautilus left Groton April 25, 1958, heading south toward the Panama Canal

[75] *Under Ice*, 101-107.
[76] *Reminiscences*, 134-35.
[77] *Reminiscences*, 108.

and the Pacific, with her crew unaware of their true destination. Preparations reminiscent of a Cold War spy novel, including false identities and elaborate cover stories, led up to the departure, and in fact would characterize much of the mission until the boat dove under the ice. Lyon was not permitted to notify his staff or even advise NEL management, a potential worry based on the equipment staff members installed when the sub pulled in to San Diego in May. Lyon had the experimental echo-sounder array used previously on USS *Carp* and USS *Redfish* installed on *Nautilus*.[78] The five-unit topside array was updated with a five-gun oscilloscope that created a workable video display of overhead ice contours. ("Five-gun" means there were five independent electron beams projected on the oscilloscope's cathode ray tube.)

Fitted out also with an inertial navigation system that could trace a voyage's route from start to finish, *Nautilus* steamed north from Seattle on June 9, but above the Bering Strait the combination of deep spring ice and shallow seas forced her to turn back, concealing the mission with a run to Hawaii. Commander Anderson had announced that mission to the crew as the sub steamed north; he now faced the challenge that more than a hundred individuals knew what only a dozen had had to keep secret before. Despite the fact his crew got liberty in Hawaii and some crewmen were given leave to fly to their homes on the East Coast while awaiting the melting of the ice, there was not a single indication anyone outside the now much wider "select circle" heard about the voyage until it was over.

During the several months *Nautilus* spent in Hawaii waiting for the ice to subside, Lyon considered the data upon which he had relied in concluding the ice would have been acceptable for passage of the submarine, which proved untrue. The source of that data had been his facility at Cape Prince of Wales, Alaska, which the submarine had passed on the way north through the Bering Strait:

> At the field station we had for a year or two kept echo-sounding systems very similar to what we had on the deck of the ship on the bottom of the strait measuring the ice that was passing back and forth through the strait, but because we had lots of other equipment in there we only sampled periodically… just sampling once or twice per day.[79]

He had studied those records from earlier in the year, but without seeking analysis to avoid threatening mission secrecy. Even at that, he acknowledged the sparse sampling meant much potentially helpful information was just missed. The result was his underestimation of the amount of ice the sub would face, especially

---

[78] *Reminiscences*, 107.
[79] *Reminiscences*, 149-150.

the ridges that were eighty to ninety feet deep, which necessarily resulted in mission scrubbing.

On July 23, 1958, *Nautilus* departed Pearl Harbor in her third approach to the pole, with Anderson in command, Lyon serving as chief scientist, and NEL's Archie Walker acting as scientific assistant. The Chukchi Sea proved navigable this time, and past that, deeper seas allowed the submarine to run comfortably at twenty knots and a depth of 600 feet. Lyon stayed at his post for 48 hours as the equipment charted depth under the boat and ice canopy thickness above.[80]

At 7:15 p.m. (23:15 GMT), August 3, 1958, *Nautilus* passed under the pole. For a moment, every point on an imaginary compass indicated south. Anderson announced the milestone to the crew, and the navigator recorded the ship's position: 90° 00.0' N.

The submarine continued south and surfaced by the coast of Greenland. Near Iceland, Commander Anderson was picked up by helicopter, beginning the journey to Washington to meet and brief President Eisenhower and receive the Legion of Merit for his leadership of this incredible accomplishment. Lyon declined the invitation to accompany him, remaining with *Nautilus* until it arrived in Portland, England, where the submarine crew received a heroes' welcome.

Honors and global acclaim followed America's answer to *Sputnik*. Lyon attended a daylong celebration in New York with evident pleasure on August 27. But his mind was already back in the laboratory and under the ice.

Skate* and *Sargo

In his lengthy oral history interview, Lyon explained the critical differences in conventional and nuclear-powered submarines:

> The diesel-powered submarine is really a surface ship that submerges, whereas the nuclear-powered submarine is a submarine which sometimes surfaces. Even after reading what [a nuclear submarine] can do, one didn't realize what that meant until one actually took part…. we'd stay submerged at whatever depth chosen for as long as required… plus the speed at which one is capable of moving at all times, up to 20 knots, which just had been inconceivable with a battery diesel operated boat.[81]

[80] *Under Ice*, 129–130.
[81] *Reminiscences*, 110-112.

For a scientist as well as a sailor, it was an entirely new world. Nuclear power vastly improved both military strategy and scientific research in the Arctic region.

USS *Skate* (SSN-578), the Navy's third nuclear submarine and the lead ship of a class of four subs, was cruising the Arctic at the time *Nautilus* made her transit of the top of the world. Under Commander James F. Calvert, *Skate* had also prepared a run at the pole, but when her sister ship achieved that milestone, Calvert and his crew (including Gene LaFond of NEL) resumed their assigned mission of charting the ice and the sea floor. *Skate* also continued to develop efficiency in surfacing in a *polynya*, an essetnail skill in the event of an onboard emergency, such as a fire or flooding, which always required a submarine to surface. Perhaps less critical, but definitely more frequent, was the need to surface to communicate, since early on in the under-ice dives no effective means was available for sending or receiving radio signals through even a thin patch of sea ice. For the cruise detailed immediately below, at the initiative of one of its officers, *Skate* carried a 160-foot floating wire antenna of NEL design. During the cruise, the antenna was deployed in an area of thin ice and received the 0900 GMT VLF (very low frequency) radio broadcast "loud and clear."[82]

In March 1959, Waldo Lyon and assistant W. E. Schatzberg traveled in *Skate* on a mission north of Spitsbergen to determine whether surfacing through ice was possible during the Arctic winter. For the cruise, NEL personnel had installed the latest version of an NK-variable frequency upward beam echo-sounder topside for determining ice thickness. The more difficult challenge was determining how thick was too thick. Shipyard personnel had hardened *Skate*'s sail with HY-80 steel prior to the voyage, and Lyon had made appropriate mathematical calculations relating area of the sail (twenty by six feet) to reasonably safe working pressure (sixty pounds per square inch) and total force of momentum when the sail impacted the ice.

The vast unknown was the strength of the ice. He had experimented off the coast at the Prince of Wales field station, and done some approximation of things like average surface temperature, but he understood sea ice strength depended not only on temperature, but also salinity, brine crystal structure, and the various pressure forces acting against the ice. Ultimately, his determination that the sub's sail could penetrate fifteen to eighteen inches of ice was an educated guess.

The Arctic Ocean's currents drive thick ice outward toward its edges; ice at

---

[82] *Under Ice*, 145.

the pole can thus at times be surprisingly thin, and the right conditions of wind and tides can create a large *polynya* at any Arctic latitude.[83] During the winter, however, virtually all open leads freeze over with several inches of ice. *Skate* searched for thinner areas in the canopy and attempted to drive upward through the ice. Little was known about the novel maneuver. For example, would gathering momentum by an accelerated vertical ascent be advantageous, or would it endanger the sail? If so, applying steady upward pressure after coming into contact with ice would be the better move. It turned out the most effective technique was easing up until the sail broke through, and then blowing the tanks to push up the final feet with as much force as possible.[84]

Waldo Lyon, keeping the guesswork part of the calculations out of the discussion, convinced the Bureau of Ships *Skate* could surface through a reasonably thin layer of ice, and Calvert's squadron commander authorized him to do so if an opportunity presented itself with no danger to the sub. BuShips had second thoughts and retracted approval before the sub sailed, but Calvert secured permission from the Commander, Submarine Force Atlantic to proceed as planned, and the sub sailed with the express intention of surfacing through ice.

After a two-week voyage, much of it under the ice canopy, and several successful surfacing maneuvers, *Skate* arrived at the North Pole on March 17. Commander Calvert spent several hours searching for reasonably thin ice and once even initiated the surfacing sequence, only to be foiled by the echo sounder's detection of thick ice overhead. Finally, in late afternoon, Calvert announced over the ship's PA system, "Stand by to surface at the pole!" and *Skate* broke through at 90 degrees north.

By the time she arrived at her home port on April 7, *Skate* had made a total of sixteen attempts to surface through the ice, ten of which were successful. Also successful was the first significant effort to operate under the Arctic ice in winter.

In 1960, Waldo Lyon and Art Roshon continued their experiments with the NEL echo-sounder and other equipment in USS *Sargo* (SSN-583), making the first winter transit of the Bering Strait and the Chukchi and Beaufort seas. These were the same waters whose short distance between ice keel and sea floor had frustrated the polar attempt of *Nautilus* in June 1958. *Sargo* carried a new sonar

---

[83] John L. Daly, "The Top of the World: Is the North Pole Turning to Water?" 7, http://www.john-daly.com/polar/arctic.htm, accessed September 12, 2014.
[84] *Under Ice*, 145–155.

A key success factor in Waldo Lyon's substantial efforts to provide the nation's submarine force Arctic capability was his providing essential navigation support culminating in surfacing at the North Pole of USS *Skate* (SSN-578) in 1959 (left) and USS *Sargo* (SSN-583) the following year. The latter demonstrated the ability to navigate the Arctic in all seasons, including during winter months.

designed by the NEL team, including Art Roshon and Frederick Parker, a veteran sonar operator on minesweepers in World War II. The sonar projected a forward signal in the frequency band between 24 and 32 kHz with a narrow four-degree vertical beam. It was much more effective than the QLA for under-ice maneuvers.

Like her sister ship *Skate*, *Sargo* surfaced at the pole. On February 19, 1960, she safely broke through four feet of ice, exposing her decks to one of the least hospitable places on earth in the dead of winter.[85]

Commanding *Sargo* for that momentous event was Lieutenant Commander John Nicholson, whose arrival in the submarine force after his 1947 graduation from Annapolis was fortuitous. One of the first two officers chosen for Rear Admiral Rickover's highly selective nuclear submarine program, he had served on the commissioning crew of *Nautilus* and as executive officer and navigator on *Skate* during its summer transit to the pole; the enthusiasm of *Skate*'s captain for Arctic exploration had rubbed off on him during the cruise. When he was assigned to command *Sargo*, Nicholson spent a substantial amount of time with Waldo Lyon, planning a rigorous month-long cruise in the extreme north latitudes for the submarine, which at launching was already fairly well equipped for the task. (Demonstrating the extent to which the fever of Arctic exploration had risen, the sub was outfitted for polar duty during her construction, with HY-80 steel hardening of her sail. Unfortunately, Bureau of Ships personnel had made the determination the "stock" submarine sonar was adequate for iceberg detection.

[85] *Under Ice*, 145–155.

Undeterred by that determination of the bureau, Waldo Lyon had worked around them and secured funding to install the latest NEL equipment on the sub before the cruise.)

Lyon and Nicholson agreed the focus of the cruise would be to determine whether it was possible during winter months for a submarine to transit from the Pacific to the Arctic basin via the shallow Bering Strait and Bering and Chukchi seas with their massive pressure ridges extending downward from the ice canopy.

Last-minute sonar difficulties required Art Roshon to scramble to the East Coast manufacturer for repair of the BQN-4 five-unit upward-beamed fathometer, which would be critical to the determination of a safe distance between the sub's sail and the ice canopy overhead. At the same time, Lyon rushed his team at NEL to send him a new transducer. Crises overcome, the submarine sailed January18, 1960. A week later *Sargo* made a scheduled rendezvous with the icebreaker USCGC *Staten Island* (WAGB-278) near St. Lawrence Island. In addition to one of Waldo Lyon's Canadian oceanographer friends who was invited for an overnight under-ice cruise on the submarine, the Coast Guard ship carried Gene Bloom, a member of Lyon's NEL division who was chief scientist of the icebreaker's oceanographic research cruise. Also aboard the icebreaker was NEL electro-optical physicist John Hood. The latter was in the middle of a four-year study of the optical properties of polar regions.[86]

After overcoming in short order some initial anomalies with the iceberg detector and serious failures of the BQN-4 and NK-Variable Frequency fathometers at a fairly critical time approaching a maze of deep pressure ridges, the sub continued toward the pole, maneuvering with a series of course changes to avoid deep ridges in the shallow water. By early evening of January 29, the boat

---

[86] J.M. Hood, Jr., "Optical Properties of the Bering Sea Naval Environment January – February 1960," NEL Research Report 1150, 18 Dec. 1962. Also, NEL *Calendar*, June 15, 1962, 1. Hood had an Arctic research facility with a "resident observer" like Waldo Lyon's Cape Prince of Wales station. It operated at the University of Alaska's Arctic Research Laboratory at Barrow, Alaska 1960-1962, collecting data on optical radiation phenomena peculiar to polar regions. The studies were useful in reconnaissance and visibility, geared particularly to concern about U.S./Russian bomber attacks via the North Pole and for "computing and predicting the optical detectability of targets… The data will be used for continuing studies of sea surface target backgrounds and for studies of remote sensing by optical means of sea and ice conditions." Automated data-collecting equipment operated twenty-four hours a day, seven days a week, measuring luminance of the sky and sun, as well as the obscuring effects of haze, fog, and blowing snow.

had completed its transit of the Bering Strait and entered the Chukchi Sea, where the water remained shallow, with even deeper pressure ridges.

Iceberg detector fails

Near Herald Island the sub surfaced, allowing the captain to attempt to establish radio communications and his divers to perform some minor repairs. The sub entered the Arctic basin around noon, after completing the first under-ice transit of the Bering and Chukchi seas in winter. Whatever feelings of satisfaction ensued from that accomplishment disappeared quickly when the iceberg detector failed a few hours later. Although not required for the moment, it would be impossible to return south through shallow seas and especially the strait without a fully operational detector.

Surfacing mid-morning on February 2 in a huge *polynya*, the extent of the problem became obvious: since nothing superficial was wrong, the 650-pound training motor mechanism, housed in a gear box and almost inaccessible, had to be removed for inspection and repair. More than twenty-four hours of two-man crews working in temperatures of 20 below zero finally freed the mechanism, but large-scale movement of the ice field forced the crew to secure the detector assembly and dive the boat. During the next undersea transit, Roshon and members of the crew cleaned up the training motor assembly, and fired it off, literally. After running a short time, the motor burned up. Nicholson's options at this point, knowing he would require that iceberg detector to transit through the Bering Strait, were to steam to the Atlantic and take the very long way home through the Panama Canal, or have Lyon's group at NEL ship another motor to Point Barrow. Roshon proposed a third alternative, which was to run the iceberg detector transducer signals through the sub's BQR-2 hydrophone assembly. There were some shortcomings to that approach, but it was potentially workable, and if so, Nicholson would not have to resort to either of the two unfavorable alternatives.

Roshon was in fact able to effect that solution, which the commanding officer termed "extremely imaginative," and the sub forged on under the ice, arriving at the pole mid-morning on February 9 and surfacing through slightly more than three feet of ice. After a little more than twenty-four hours at the pole, during which the communications backlog was cleared, Nicholson ordered the sub to make a stationary dive, which required several attempts to break the bond the ice had made with *Sargo*'s hull. Recognizing from the experience how little was known about submarine bonding with sea ice, Waldo Lyon resolved to revisit that problem when he had the opportunity to return to NEL and his arctic pool.[87]

Cruising the Arctic Ocean heading toward the McClure Strait, the sub encountered a deep bottom, but pressures ridges from the ice canopy extended downward to great depths, averaging 75 to 95 feet. Ten ridges reached depths in excess of 100 feet; one projected downward to 122 feet. The sub continued south for two weeks, dodging multiple deep-draft pressure ridges, colliding with one, resulting in minor damage to the sail. Otherwise proceeding at a good pace, the sub reached open water on February 25. *Sargo* surfaced shortly after noon, to a flood of well wishes in radio messages from Naval Submarine Force and Pacific Fleet officials.

Captain and crew awarded

With arrival at Pearl Harbor on March 3, Lieutenant Commander Nicholson received the Legion of Merit, and the boat and crew, plus its two NEL scientists, received the Navy Unit Commendation. Several months later, one of the latter, Art Roshon, was presented the Navy's highest award, the Distinguished Civilian Service Award, for the initial work on the under-ice sonar, and, "Further, by an ingenious modification, he accomplished the repair of the Iceberg Detector when mechanical failure occurred during the cruise."[88]

In the March 6 entry in his scientific journal, Waldo Lyon termed the experience "the most fabulous patrol of my career." Revisiting that entry in 1996, he added, "Still true."

In his oral history a decade later, Lyon commented about the methodology of that cruise and perhaps the *Skate* cruise the year before, that they were "the ultimate of a situation where the engineer-scientists and the operators were working together. We were doing the experiments and the design and everything right there, right on the scene..."[89]

[87] *Under Ice*, 174.
[88] Navy Electronics Laboratory *Calendar*, 4 November 1960, 1.
[89] *Reminiscences*, 193.

Half a century later, Nicholson agreed:

> Especially as we were starting out with this, trying to pinpoint what the sonar was showing us, we were leaning very heavily on Waldo or Art Roshon… to make sure that we felt comfortable and later on when we had troubles… we leaned very, very heavily on Art Roshon.[90]

Beyond the immediate success of the specific cruise, Nicholson summarized the "great benefits" for the Navy "in how far Waldo was ahead of his time," that

> our submarines started having the ability… to go from the Atlantic to the Pacific and save all that time and space of getting over into the other ocean, and he would put an ice pilot on each submarine and he would train the crew before they got underway, and then would be on-board to be of help for the transits… It's not only cheaper and safer, but it's completely undetectable, and so the submarine can wind up in Japan, for example, starting out from New London…

Waldo Lyon, he said, "had intelligence, drive and he could make things happen that you wouldn't have thought possible. A real hero in my opinion."[91]

An effort to stage a polar cruise for *Skate* a few months after the *Sargo* voyage fell through when higher authority deemed there were insufficient submarine forces to meet requirements for ASW training. Nevertheless, a cruise occurred, and an important one, as the office of the Chief of Naval Operations selected the newly commissioned USS *Seadragon* (SSN-584), built in Connecticut, to join the Pacific Fleet by steaming across the country via the Arctic Ocean. With Lyon and Roshon aboard to test new NEL scanning equipment for icebergs, the boat made a shallow-water expedition through the Arctic Basin via the Northwest Passage.

While an enticing newspaper headline (that and the softball game played at the North Pole), Lyon believed the substantially more significant achievement during that cruise was the transition from experimental to operational:

> …what else we did with *Sea Dragon* [sic] was to let the ship do more and more of the decision and operating. And the engineers stayed out of the picture to see how the ship's crew and officers would handle the equipment, because, after all, the next step was to get this to be a complete Navy uniform operation… So, really, with the close of *Sea Dragon* [sic] it was kind of close of chapter for the engineer experimental trial period, and the scanning sonar equipment then shifted from the experimental prototype into an actual production model.[92]

Plans for submarine activity in the Arctic the following year were scrubbed based on delays in installing polar equipment on the proposed boats, but two

---

[90] Vice Admiral John Nicholson, USN (Ret.) in phone interview December 18, 2013 with Tom LaPuzza.
[91] Vice Admiral Nicholson phone interview.
[92] *Reminiscences*, 228-9.

subs—*Skate* and *Seadragon*—were both sent north the following year, from the Atlantic and Pacific coasts, respectively, not only to continue collection of bathymetric data critical to future operations, but also to conduct war games. On a mid-cruise day otherwise dismal through multiple torpedo failures, there was an extremely bright light: John F. Kennedy presented the nation's highest civilian award, the President's Distinguished Federal Civilian Service Award, to Dr. Waldo Lyon. Lyon's wife Virginia accepted the award for her husband, who at the time was observing the unsuccessful operation of the Mark 37 anti-submarine torpedo from *Skate*, preparing to move to *Seadragon* the next day or so.[93]

The award citation is instructive in that it frankly describes the challenges Lyon overcame, many of them from the Navy which he served faithfully:

> He has been singularly responsible for the pioneering development of the knowledge, techniques and instruments that made it possible for a submarine to navigate under the ice cap in the Arctic. In the face of formidable obstacles he persevered in believing that transarctic submarine navigation could become a reality and directed his efforts toward this objective. His achievement represents a highly important contribution to the Nation's security.

The Navy declined to provide a submarine for Arctic cruises for the next several years, for reasons administrative (even in 1967 there were people in influential places, such as the OPNAV Submarine Warfare Division, who considered Arctic capability of little value); general (submarine shortages); and specific (loss of USS *Thresher*).[94] In the face of that, Waldo Lyon worked on growing true sea ice in Battery Whistler and former *Sargo* commanding officer Commander John Nicholson worked in the Pentagon to get a submarine "factory equipped" with Arctic capabilities. He succeeded, to the delight of Lyon, who called him "singularly responsible" for the under-ice capability of the new SSNs.

In his retirement story three decades later, Lyon noted, "When the *Sturgeon* (SSN-637)-class came out [first boat…1967]—with their hardened sails, rotating

[93] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*, 1990, 71–72. Also, *Under Ice*, 218–219.

[94] *Thresher* (SSN-593), lead ship of a new submarine class, sank with 129 crewmen and civilian technical personnel off the Massachusetts coast during deep-diving tests on April 10, 1963. A substantial investigation followed, including dispatching the San Diego Navy lab's bathyscaph *Trieste* to locate the wreckage, and significant changes in U.S. Navy submarine operational procedures resulted from the investigation findings.

sail planes, ice-avoidance sonar, upward-looking sonar to characterize the ocean overhead, and inertial navigation system—we ran them to death."[95]

Both Art Roshon (left) and Dr. Waldo Lyon [greeted upon his return from the USS *Nautilus* (SSN-571) North Pole cruise] received the highest honor, the Distinguished Civilian Service Award, for separate and combined submarine cruises at the top of the world.

Over those three decades, Lyon, Roshon, and their associates, particularly the members of the Submarine Research Facility—which was renamed more appropriately the Arctic Submarine Laboratory in 1969—developed increasingly sophisticated and effective under-ice navigation and iceberg detection sonars; spent days and weeks sharing the hardships of submarine crews operating in the Arctic; and studied the physics of sea ice in their laboratory pool. Highlights of the first of those decades:

--Early 1967 cruise of USS *Queenfish* (SSN-651), first *Sturgeon*-class boat to go to sea, including first operational testing of the new AN/BQS-8 sonar and steaming almost a hundred hours and more than a thousand miles under the ice

--SUBICEX 1-69, an extremely ambitious exercise which involved three nuclear submarines—*Skate*, USS *Whale* (SSN-638), and USS *Pargo* (SSN-650)—and had three objectives: testing the ability of SSN-637 class boats to break through the ice, assessing the detection capability of the Sound Surveillance

[95] NCCOSC RDT&E Division *Outlook*, November 1, 1996, 3.

System in the Norwegian and Greenland seas, and testing of modified Mark 37 torpedoes.

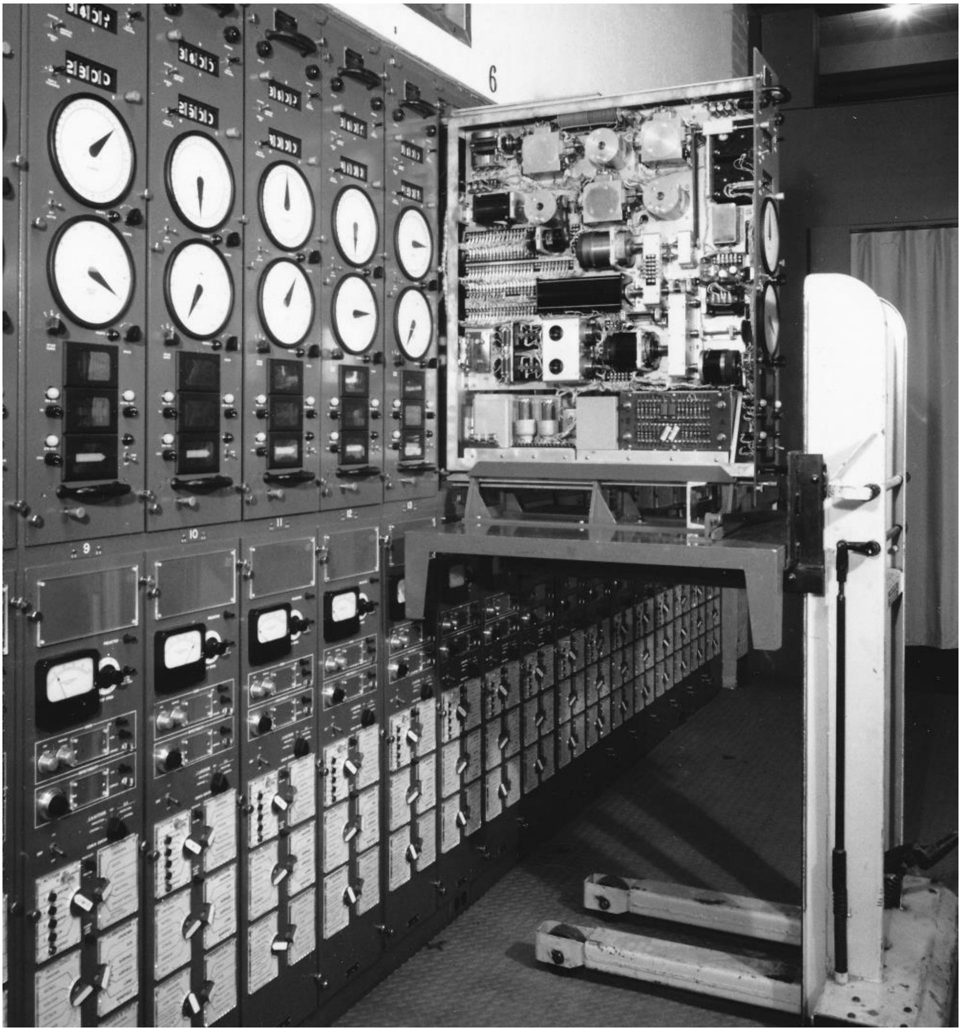
In Volume II, we will resume our discussion of the Arctic capabilities provided to the Navy by Dr. Waldo Lyon, Art Roshon, and their associates in the Arctic Submarine Lab. While we will repeat this in the second volume, it bears initial notice: Dr. Lyon passed away in 1998, having given half a century of his life to the support of the U.S. Navy submarine force. A year later, a nuclear submarine surfaced at the North Pole, based on capabilities for which Waldo Lyon was substantially responsible. Honoring him in the most appropriate manner, they placed his ashes on an ice floe there.

It is a reasonable comparison that Waldo Lyon and Art Roshon were in many ways the human equivalent of NTDS in the Arctic submarine environment. Contrary to the visceral expectations of some surface ships COs ("No damn computer is going to tell me what to do!"), the NEL sonar experts, like NTDS, merely provided valuable information on the "bogeys" of concern: "Pressure ridge down to eighty feet dead ahead at fifteen hundred yards!" The decision was always the commanding officer's, although the ice keel dead ahead that could effectively destroy his submarine pretty much forced the decision. The responsibility of Lyon, Roshon, and other personnel of the Arctic Submarine Laboratory on later cruises was, like that of an NTDS, to provide accurate and timely information on which to base those decisions and to develop the equipment to collect and present that information in the first place. To a substantial degree, that has been the most significant role of the Point Loma Navy lab for decades.

The electronic age

As would be expected, NEL's technical development work during the 1950s and 1960s not only mirrored but often led progress across the spectrum of electronic technologies, which was substantially focused on the leap from analog to digital. An effort that began shortly after World War II to develop a realistic war gaming technology for the Navy involved a substantial number of laboratory engineers for more than a decade and a half in a project representing that progress.

The first five years were spent understanding and characterizing the requirement, followed by the design and development phase beginning in 1950. In 1954, work began on the actual system, which was assigned the following year to the Naval War College for direction and operation. The intent was to develop a



NEL technologists took five years to understand and characterize the elements of the Naval Electronic Warfare Simulator (NEWS), then designed and built it, filling three stories of a building at the Naval War College.

technology that would simulate battle—essentially a two-sided war game—decades before video gaming. The final product, the Navy Electronic Warfare Simulator (NEWS), occupied three floors of a building in Newport, Rhode Island. Operational by May 1958, it allowed positioning up to two hundred personnel in rooms built to resemble a ship's combat information center.

Players were informed of their own situation but not that of other teams—similar to real combat conditions—and the status of ships and weapons changed according to what different "forces" did. The laboratory's in-house newspaper reported NEL acted as technical director and designer of most of the equipment.[96]

According to the letters of commendation received by fifteen NEL employees who were presented initial and then additional monetary awards,

> The NEWS represents the first development of a device which can present the simulation of many aspects of naval warfare at the command, or decision-making level. Considerable original thought was required in its design and development, and the resulting installation is tribute to the effort and dedication of you and your associates…[97]

The development group was led by Charles S. Manning, who near the end of this effort would switch his attention to NTDS (as noted earlier in this chapter). The newspaper article went on to say NEL was currently preparing instruction books containing about three thousand pages of technical information, illustrations, and diagrams. Nearly three thousand pieces of nomenclature equipment of 263 different types were involved in the project. In addition to the design leadership role, the lab fabricated about forty percent of the equipment.

LORAD

Waldo Lyon's loss of a submarine platform with which to study thermal layers of the waters in and around the Arctic Ocean was a gain for his NEL associates developing submarine sonars. A group at the laboratory's waterfront area not only modeled sonar transducers, but designed first articles and built them,

---

[96] U.S. Navy Electronics Laboratory *Calendar*, March 30, 1962. See also NELC *Calendar*, March 13, 1970. Also, Francis J. McHugh, "Fundamentals of War Gaming," United States Naval War College report, April 17, 1969, 5-3, 5-11.
[97] NEL *Calendar*, March 30, 1962.

firing piezoelectric ceramics in a large kiln. The group made its own transducers and transducer arrays in developing innovative sonar systems.[98]

Access to USS *Baya* provided the group a perfect platform for deploying and testing developmental sonars. One of the earliest was a large active research sonar system called Long-Range Active Detection (LORAD), intended to extend underwater detection range substantially. Pioneering techniques employed in system development included pseudo-random noise correlation signals, digital programming, and billionth of a second electronic clock accuracy.

According to a 1960 laboratory publication, the system was

> a method of echo ranging devised by NEL that makes use of the sound refraction paths existing in deep ocean areas (about 2000 fathoms or greater)… the first research system installed on the USS BAYA achieved detection of submarines in the first and second convergence zones at ranges of about 34 to 67 miles.[99]

The sonar was so large installation required a visit to the San Francisco Naval Shipyard in fall 1958, where the typical knife-edge bow was replaced by a bulbous nose to accommodate the array and to add quarters for additional crew and civilian scientists.[100] The first such array was composed of magnetostrictive transducers, but it was soon replaced with a more conventional piezoelectric array. According to long-time sonar developer Morris Akers, the project substantially benefitted later fleet systems:

> A tremendous amount of the research and knowledge that was gained from the LORAD project, for design and manufacturing of both transducers and electronic amplifiers with both passive and active arrays, has been integrated into fleet and commercial sonar systems.[101]

NEL took great pains to document the effort, publishing a thick summary report in 1956 with input from forty authors.[102]

---

[98] C.E. Green, F.M. Uber, and R.M. Lewis, "The Fabrication of Large Ceramic Cylinders for Sonar Transducers," Navy Electronics Laboratory Report 846, 29 May 1958. See also: Morris Akers, oral history interview conducted by Tom LaPuzza, February 7, 2013, 3.

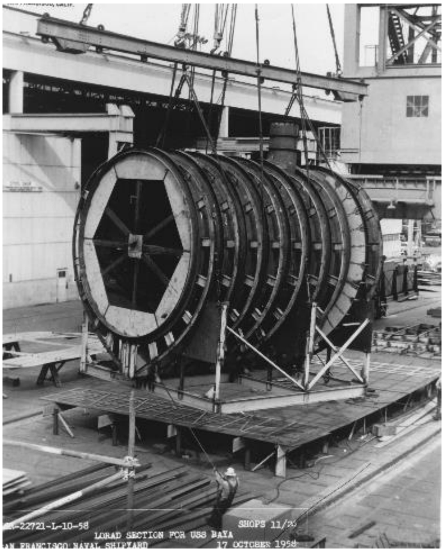
[99] "NEL Technical Progress Report 1958," NEL Report 860, 1958, 11.

[100] Commander Robert Loys Sminkey, USN (Ret.), "USS Baya (SS-318) Ship's History," found at http://www.subvetpaul.com/USS-Baya-SS-318.htm visited August 25, 2017.

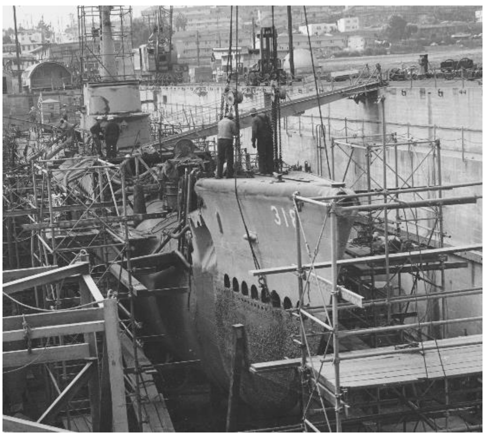
[101] Morris Akers email to Tom LaPuzza, January 20, 2014.

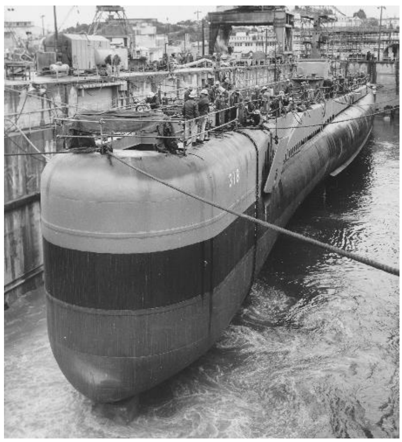
[102] R.G. Stephenson, Coordinator, "LORAD Summary Report," NEL Report 698, 22 June 1956.

An unusual piece of equipment aboard *Baya* was a single AN/USQ-20 general purpose, stored-program computer. Jim Gilbreath, an electrical engineer who worked with early NEL computers and would later head the Naval Ocean Systems Center Computer Technology Division, was responsible for the USQ-20.



The Long Range Active Detection (LORAD) sonar was so massive it required a visit to the shipyard of USS *Baya* (AGSS-318), where a radical transformation of its bow was effected.





Commenting on the challenge of dealing with the first of its kind, he related,

> It was Serial Number 1, the first digital computer aboard a Navy ship. Because it was to go aboard our submarine and would not fit through a 25-inch hatch, we got UNIVAC to make two cabinets, one to have ashore in a lab that I ran and one to have aboard the ship. The cabinet was taken apart and passed down through the hatch and then reassembled. It had twelve drawers that could slide in and out of the chassis with an elaborate mechanical cranking system to engage all the connectors at the sides. The drawers would go through a 25-inch hatch. The computer controlled the [LORAD] sonar system during sea tests… The computer looked like a big gray refrigerator with double doors. It was about six feet high and four feet wide and deep… We also had a paper tape reader and a paper tape punch. That was the only way to get programs and data in or out of the memory, other than binary button pushing on the control panel.[103]

When *Baya* returned after a sea test, the plug-in drawers were disconnected and hauled up to Building 128, where the equipment was plugged back in and used to debug data processing programs so LORAD sea test data could be analyzed.[104]

Other sonar development continued both in the laboratory and in the field. By the early 1960s, sonar systems using towed arrays were deployed in ASW applications. NEL developed the AN/SQQ-16 towed array, a leap forward in passive sonar. Resembling an old-fashioned library globe in its stand, the array enabled high-resolution target classification.[105]

Employees of the laboratory turned their attention in a different direction with the construction of the first West Coast tracking station for the International Geophysical Year 1957–1958, and in particular for the Vanguard program. The station, located one and a half miles north of the U.S./Mexico border at Brown Field (now a general aviation airport), was the first non-Soviet facility to follow *Sputnik*. In the years immediately following, it tracked the American Vanguard satellites.[106] NEL added a 60-foot parabolic radio telescope on Point Loma in 1961 to support satellite communications projects and conduct experiments on the physics of high-frequency radio waves.

---

[103] Jim Gilbreath oral history interview conducted by Tom LaPuzza, November 28, 2017, 6.

[104] NEL Command History 1961, 7. See also: "First Time: New Computer Facility Readied for Use in '61," NEL *Calendar*, 2 December 1960, 6.

[105] *Fifty Years*, 70.

[106] *Fifty Years*, 45 & 62; San Diego Airports: http://www.sandiego.gov/airports/brown/, accessed March 17, 2015.

Other work

The post-World War II/early Cold War era was characterized at NEL by expansion into a variety of technology development areas. While communications antennas and underwater sound research continued to dominate, laboratory scientists and engineers branched out into other disciplines that allowed their creative genius to show itself, including such subjects as navigation, lasers, mine hunting, and even dental research. Some key examples of that work are:

*Navigation***:** Radux was a low-frequency radio navigation system developed at the lab during the early to mid-1950s. It allowed a ship or aircraft, keying off three time-synchronized locations—San Diego, Hawaii, and Bainbridge Island, Washington—to determine its position within two nautical miles.[107]

Visibility and camouflage: A Massachusetts Institute of Technology group formed shortly after World War II to study penetration of daylight into bodies of water and visual sighting of underwater objects came to the attention of Dr. Walter Munk and Dr. Roger Revelle of Scripps. At their suggestion, the Navy's Bureau of Ships (BuShips), which was funding the group, moved significant portions of the Visibility Lab to San Diego in 1952. The lab was sited in NEL's Barracks Area and eventually became part of Scripps, which operated a field annex there.[108]

Based on Navy interest, NEL established its own Visibility and Concealment Branch, offering leadership to John Hood, a Visibility Lab senior engineer, who transferred to NEL and initiated its visibility and camouflage program.[109] Although the Vis Lab and the NEL Visibility Branch were distinctly different entities, the two organizations worked on similar problems and technologies, both funded by the same BuShips assignment desk.[110] On occasion, they collaborated on projects of mutual interest, including the study of optical radiation phenomena at John Hood's Arctic Research Laboratory discussed above.

Hood's laboratory spaces were in the original Navy Radio and Sound Lab headquarters, Building A4. One of his projects was to research camouflaging a submarine; to that end his group conducted studies with a small model sub, using

[107] *Fifty Years*, 44.
[108] Ross Austin, last Visibility Lab director, in phone conversation with Tom LaPuzza August 30, 2017.
[109] NEL *Station Journal*, 9 October 1952.
[110] John Hood email to Tom LaPuzza, May 25, 2012.

the laboratory pool in that building (see Chapter 3). After the experimentation, "we had the pool filled in so that Erhard could have a decent lab," he wrote.[111]

Lasers: Hood was referring to Dr. Erhard Schimitschek, "an accomplished Ph.D. chemist" NEL hired away from private industry in 1960 "to investigate the possibility of developing a blue green liquid laser." The laboratory pool was demolished and filled with debris from the refurbishment, providing Schimitschek "a first-class chemistry research facility."

Dr. Schimitschek apparently found the facility to his liking, since it allowed him to develop the first successful laser cavity using a liquid laser material there, "Europium, Element 66 [sic. It is actually element 63], combined with a ring molecule of benzoylacetonate, to demonstrate a visible beam of coherent radiation, a big step in developing a laser that could be used for communications or surveillance."[112]

It was the beginning of a long and fruitful effort on the part of the Point Loma Navy lab to develop laser technology in support of its assigned mission (see Chapter 10 for additional information on laser research).

Mine-hunting: NEL pursued other interests in underwater acoustics, some of which foreshadowed similar work by the Naval Ordnance Test Station (NOTS) at China Lake that would occur several decades later. For instance, concerned that a "... determined Russian sea mine offensive could seal the harbors of Great Britain and Japan, deny the use of European and Asiatic coastwise war channels, and prevent amphibious retaliation," the lab collaborated with the National Research Council during the Korean War to find a means using underwater sound techniques to locate and destroy sea mines.[113]

A later report concluded bottom mines could be detected using underwater acoustics, but not buried ones.[114] Still later, a researcher posited sonar pulses could be employed to locate buried targets, but the search time requirement was prohibitive.[115] The Navy's Mark 7 Marine Mammal System, developed many

---

[111] John Hood email to Tom LaPuzza, August 9, 2017.
[112] *Fifty Years*, 78.
[113] E.A. Walker, "The Cooperative Research Program of the Navy Electronics Laboratory and the National Research Council on Bottom Sea-Mine Countermeasures–June, July, August 1951," Vol. 1: Conspectus of Program, NEL Report 265 of 21 August 1951, 4.
[114] R.B. Watson, "Detection of Buried Mines-Exploratory Experiments," NEL Report 355, 26 February 1953
[115] J.C. Hayes, "Detection of Buried Targets by Acoustical Means: A Feasibility Study."

years later at the NOTS/NEL-successor Naval Ocean Systems Center's Hawaii Laboratory, would solve both these problems.

Similarly, and in the same time frame, NEL pursued underwater acoustics technology in detection of divers,[116] which Hawaii Lab marine mammal experts would manage successfully with the Mark 6 Marine Mammal System and operationally deploy to Vietnam in the early 1970s (see Chapter 8).

Acoustic studies: In 1967, NEL's Transducer Evaluation Center was employed for acoustic studies "on a deep dunk diving array" twelve feet high and weighing more than a ton.[117] Not mentioned, undoubtedly due to classification constraints, was that the device was the "Deep Dunk vehicle" of the Sonaray project, an effort by the NOTS Pasadena Lab to develop a "semiautonomous vehicle that would travel with a naval convoy to protect it from enemy submarines."[118]

Dentistry: And, as if there wasn't a multitude of interesting projects going on, consider this: an electronics laboratory conducting dental research, as NEL established a "Dental Research Branch To Study Tooth Decay."[119] Attendees at a ribbon-cutting ceremony, including the chief of the Navy's Dental Division, toured a lab set up "to determine the electrical conductivity characteristics of human teeth."[120] The stated purpose of the research, headed by a Navy captain, was to predict the potential for tooth decay before it occurred. Despite the oddity, NEL was not without credentials in this area, having provided assistance on a dentistry "problem" (the early nomenclature characterizing a project) for at least a decade.

Facilities upgrades

In addition to the groundbreaking detailed at the start of this chapter, and subsequent construction of a new headquarters building for the Navy Electronics

---

NEL Report 457, 1954.

116 H.L. Bechard and C.V. Tenney, "Underwater Radiated Noise and Target Strengths of Swimmers Using Aqua-Lung and Laru Equipment," NEL Report 459 of 12 January 1954.

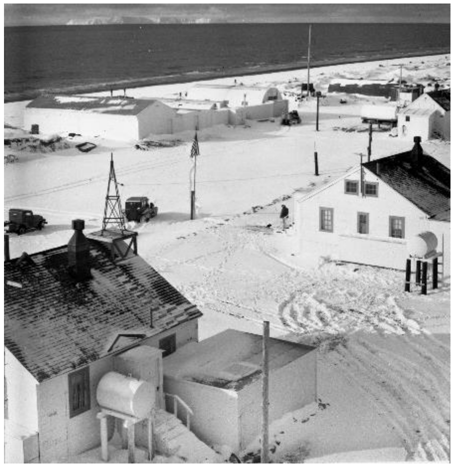
117 "NOTS Capsule Undergoes Test," NEL Calendar, June 9, 1967, 1.

118 Cliff Lawson, *History of the Navy at China Lake, California, Volume 4: The Station Comes of Age* (China Lake, California: Naval Air Warfare Center Weapons Division, 2017), 450.

119 NEL *Calendar*, January 24, 1964, 2.

120 NEL *Station Journal*, 16 January 1964.

Laboratory, there were several facilities projects in the 1950s and 1960s that contributed important resources for the lab. For example, upgrades continued at the Model Range with the 1958 construction of the zenith arch, a 78-foot-tall curved wooden cantilever structure towering over the model turntable with a track to carry an antenna high in the air (to elevations of 65 degrees) to transmit to or receive signals from the model's antennas.[121]



The nature of its work required the Point Loma Navy lab to acquire or develop unique facilities and equipment. Significant among those were (top left and right) Oceanographic Research Tower a mile off a San Diego beach and the facility at Cape Prince of Wales, Alaska; the "facility" that consisted entirely of a barge on Lake Pend Oreille, Idaho, and the Thermistor Chain.

[121] "NEL Technical Progress Report 1959," NEL Report 915, 30 June 1959.

At the same time, in sixty feet of water a mile off San Diego's popular Mission Beach, Eugene LaFond's design of an ocean laboratory for *in situ* studies of the marine environment was being constructed. Completed in 1959, the Oceanographic Research Tower provided the stability of a land-based laboratory but with immediate access to "open ocean" waters (see Chapter 10 for details). For studies in deeper water, especially related to temperature profiles, a ponderous device was installed aboard the NEL support vessel USS *Marysville* (EPCER-857), again at the direction of oceanographer LaFond, in 1961.[122] The thermistor chain, a depth-vs.-temperature device, was a 19-ton, 900-foot-long string of "thermistor beads," temperature sensing devices spaced every 27 feet along the chain. Operating and recording temperatures continuously every ten seconds as the Marysville steamed across the ocean at up to ten knots, the device recorded "lines" of temperatures related to depth, allowing scientists "to observe and study layers of water in a large section of the ocean almost at the same time," to gain immediate understanding of "the physical characteristics of the thermocline in two dimensions in the boundary surface between warm and cold water."

In addition to studies of the Gulf of California and along the equator, the *Marysville*-thermistor chain combination recorded temperatures across the Pacific from San Diego to Honolulu and in the Bering Sea as part of the extensive NEL studies resulting in operation of submarines in the Arctic.[123]

The Point Loma lab's "fleet" has often included small vessels, such as the patrol craft *Marysville* and her sister ship USS *Rexford*, and later with their merger in 1977 the Naval Undersea Center's torpedo recovery boats, plus some larger draft oceanographic research ships. Only once has it included a massive aircraft carrier.

USS *Bunker Hill* (CV/CVA/CVS-17 and AVT-9) came to NEL in December of 1965 as a program test bed. A World War II-era *Essex*-class carrier that served during the second half of the war in the central and western Pacific, the ship was berthed at North Island to support NEL's participation in the Southern Cross project and, later, as detailed in Chapter 10, for development of critical internal shipboard command, control and communication systems.

---

[122] "Thermistor Chain Readied for Ocean Study," NEL *Calendar*, 14 July 1961, 1. See also: Eugene LaFond, "Thermistor Chain," NEL Report 1114, 20 June 1962.
[123] NEL *Calendar*, March 12 and July 9, 1965; January 14 and July 1, 1966.

Two huge (60-foot-diameter) dishes were also fabricated and installed during this period, one on Point Loma and the other in the Laguna Mountains some sixty miles to the east, to support satellite communications research. These will be discussed in a later chapter.

In addition to oceanographic towers and communication arches and aircraft carriers, NEL gained land as well, when the Eleventh Naval District in the spring of 1959 assigned local command and plant property responsibility to the lab for the Fort Rosecrans Reservation, in effect making it the "landlord" of an additional 577 acres and 134 buildings and structures of various descriptions.[124]

Test facilities

And far to the north, on a unique lake in northern Idaho, NEL had set up a small facility, essentially without any land, several years earlier. The lab awarded a commercial contract for the construction of a test barge and, on July 21, 1952, officially established a calibration station on Lake Pend Oreille, at the site of the David Taylor Model Basin field station.[125] Because the lake is isothermal, with the same temperature essentially from top to sometimes very deep bottom (at 1,150 feet, it is the deepest lake in Idaho and the fifth deepest in the nation) year-round, it lent itself remarkably well to the testing of sonars and sonar transducers. NEL and its successors tested a number of those transducers there, operating from a barge in the middle of the lake for decades. San Diego personnel regularly tested equipment at the lake, supported by approximately a half dozen permanently assigned lab employees. The first of those were R.W. Schillereff; Glen Stanley; A.V. Huntley, Jr.; and Vernon G. Price. Price, a physicist, was designated the senior scientist.

---

[124] *Fifty Years*, 39.

[125] Navy ship architect and engineer David Watson Taylor (who retired as a rear admiral) constructed a model basin to test new ship designs at the Washington Navy Yard in the late 1800s. The facility moved to Maryland just prior to World War II. Today it is the Naval Surface Warfare Center's Carderock Division. The organization, at the time officially the David Taylor Model Basin, established a field station for acoustic and underwater countermeasures tests in Bayview, Idaho, on Lake Pend Oreille in 1946. NEL took advantage of the Navy presence there to satisfy its requirement for a test facility with unique physical characteristics.

Other than some parking places and storage/equipment sheds, the lab had no facilities on actual land at Pend Oreille.

One of the principals in the use of the lake's test facilities was physicist Charles Green, who had spent a number of years in east San Diego County at Sweetwater Reservoir calibrating transducers for underwater acoustics studies. When the reservoir's level was allowed to recede dramatically, he required another venue for his calibration work and devised a plan whereby he would scoop out truckloads of Point Loma dirt and fashion his own calibration resource. The result was the Transducer Evaluation Center, an elliptically shaped anechoic pool. Construction of the pool, which Green personally supervised and which earned him a presidential citation, will be discussed in a later chapter.

As the "post-war era" gave way to the excitement and challenges of the 1960s, the Navy Electronics Laboratory demonstrated an increasing ability to attract and retain top-level professional personnel and a growing maturity in the pursuit of its program work. Similar trends were occurring a hundred miles to the north in Pasadena.

Dr. Robert S. Dietz

When Robert Dietz received his Ph.D. in marine geology, the discipline was not yet recognized as a scientific field, and finding employment was problematic. Fortunately, he had joined the Reserve Officers Training Corps as an undergraduate, and he was called up to active duty with the Army Air Corps.

After his military service, he was invited to join the staff of the Navy Electronics Laboratory, to establish a sea floor studies group. His activities in that role included participation as a geological oceanographer in Operation High Jump, the Navy-sponsored expedition to Antarctica in 1946-47, which explored and mapped large areas of the continent, and in joint oceanographic cruises of NEL and Scripps Institution of Oceanography. (Although his advanced degrees were awarded by the University of Illinois, most of Dietz's graduate work was done at Scripps, and during most of the seventeen years he worked at the Navy lab he also served as an adjunct professor at Scripps.) Most notable of these joint cruises was the landmark MidPac Expedition in 1950, based on which Dietz produced four published papers (two with expedition associates). Particularly noteworthy was his account "of an imaginary voyage in a supersubmarine," in which he adopted the style of storyteller to relate the geological features of the sea floor.[126]

Dr. Robert S. Dietz

NEL was one of the first organizations to purchase "aqua lungs" (today's Self-Contained Underwater Breathing Apparatus—SCUBA gear); Dietz and his Navy and Scripps associates made substantial use of the new capability for gaining first-hand knowledge of the shallow undersea environment, including studying evidence of erosion in submarine canyons in the Gulf of California.[127]

Dietz spent most of the mid-1950s out of the country, first as a Fulbright scholar at the University of Tokyo and for the next five years assigned to the Office of Naval Research (ONR) facility in London. He was fortunate at the time to meet Jacques Piccard, son of *Trieste* inventor Auguste Piccard. From his SCUBA

[126] Robert S. Dietz, "The Pacific Floor," *Scientific American*, Vol. 186, No. 4, April 1952, 20-23.

[127] "SCUBA Technique Important as Research Tool; Widely Used at NEL," NEL *Calendar*, 3 June 1960, 2, and "NEL Participates In Diving Expedition To Study Erosion In Submarine Canyons," NEL *Calendar*, 30 March 1962, 3.

experiences, he understood the value of putting a human scientific observer in the ocean to study its processes first hand and the even greater value of a platform like *Trieste* to put one in the inhospitable deep ocean. (He was the first American to dive in the bathyscaph.) He represented that value to ONR and was instrumental in U.S. Navy support to complete bathyscaph construction and bring it to NEL for underwater studies. As detailed in Chapter 8, his coordination efforts resulted in a world record for NEL. It also resulted in his being presented the Navy Superior Civilian Service Award, the Navy's second highest, by none other than Chief of Naval Research Rear Admiral Rawson Bennett, who had been director of the Point Loma Navy laboratory when Dietz started to work there.

Following the historic "Deep Dive," he collaborated with Jacques Piccard on a volume describing the effort.[128]

Dietz's most significant scientific contribution originated in his early work with the NEL sea floor studies. Seeking explanation for anomalous observations relative to ocean bottom composition and as a result of studying Pacific seafloor fracture zones, he advanced the theory that the seafloor was constantly, if slowly, moving. He presented the theory in a 1961 paper, in the title of which he coined the now common term, "seafloor spreading." In it he states, "The gross structures of the sea floor are direct expressions of this convection. The median rises mark the up-welling sites or divergences; the trenches are associated with the convergences or down-welling sites…"[129]

---

[128] Jacques Piccard and Robert S. Dietz, *Seven Miles Down* (New York: G.P. Putnam's Sons, 1961).

[129] Robert S. Dietz, "Continent and Ocean Basin Evolution by Spreading of the Sea Floor," *Nature*, June 3, 1961, Vol. 190, 854; see also Dr. Robert S. Dietz, "A Theory of Ocean Basin Origin," *Undersea Technology*, January 1963, 26-29.

7

The Rattlesnake in the Desert

Buried in sand of colors matching the pattern of its skin, it waits patiently, the hoods over its eyes warding off blowing grains, its pit organs tuned to the surrounding desert floor. The oppressive summer heat has faded, and diurnal hunting has replaced nocturnal. Inviting attention, a desert woodrat seeking seeds and buds skitters over the loose sand among the creosote bushes and occasional cactus, its whiskers bristling with the effort to orient itself while it seeks to alleviate its hunger. The heat-illuminated target wanders closer, then away, then back again, pausing at a prickly pear cactus for water. A flash of movement too fast to be seen is followed by searing pain; a terrified survey of the sands shows nothing but desolation, as numbness rips away the ability of small legs to flee. Darkness and death come quickly.

When the rat's death twitches subside, a two-foot tube of muscle and scales and elongated internal organs slithers in a strangely sidewise fashion out of the loose sand that has camouflaged it: *Crotalus cerastes cerastes,* the Mojave Desert sub-species of venomous pit viper familiarly known as the sidewinder rattlesnake, unhinges its jaws to swallow the rodent.

It is a couple of days after Thanksgiving in 1950. In a conference room built by humans not far away, a group of Navy civilian physicists and engineers is meeting to confirm their project, initially titled "Control System and Fuze for the High-Performance Air-to-Air Rocket," will henceforth be known by the same name as that pit viper. They agree that in ten months they will have solved myriad problems of navigation, momentum, and aerodynamics to enable the first major test of their heat-seeking missile, designed to strike out in a deadly fashion like its namesake against fast-moving aircraft. They will err in the scheduling calculations, but ultimately, with patience approaching that of the viper hidden in the loose sands of the Mojave Desert surrounding them, they will demonstrate the deadliness of their purpose.

The leader of this small group is Dr. William B. McLean, who came to this vast Navy empire of sand and scrub and snakes in 1945 to begin an astounding career as a career government scientist. Fairly early on in that career it would occur to his brilliant mind that a fire-control system for an aircraft seeking another aircraft as a target would quickly become too complex for the pilot to manage, and so, instead, he should "use some property of the target itself as a means of guiding an air-to-air rocket."[1]

Before that milestone meeting essentially marking the formal beginning of Sidewinder missile development, McLean had already advanced from his initial position heading the Naval Ordnance Test Station Ordnance Department's Fire-Control Section to managing the Aviation Ordnance Division. The following year, early 1948, he had begun work "on a seeker homing on infrared (IR) radiation." He was virtually alone in considering IR (essentially heat) as a reasonable signal for a weapon to track; unconcerned, he pushed forward and a year and a half later published his first formal proposal for the weapon, a report that "stressed simplicity, reliability, small size, ease of use and low cost as program goals…"[2]

McLean had spoken on several occasions about his heat seeker to a variety of audiences, but the selected attendees at the 1950 meeting were those who had listened with enough enthusiasm to go out on their own and experiment with the portions of the idea that interested them.

For his part in the process, McLean described his method of inquiry this way:

> You start with the system—what is it you want to accomplish? Then you decide what technology [is] available and what the tradeoffs are that you have to make [to] accomplish the purpose you want to achieve. Like in the air-to-air rocketry and the air-to-ground rocketry, we first had to find out what was causing the biggest errors. Rockets weren't going where you thought they ought to go, and once you had all the factors straightened out then you could go about correcting the ones that were the most important.[3]

McLean was selected to head the NOTS Aviation Ordnance Department in 1950. His meteoric rise within the organization—section head to division head to senior management department head in a mere five years—presented some difficulties. Like his handful of fellow department heads, he had an organization

---

[1] Elizabeth Babcock, *History of the Navy at China Lake, California, Volume 3: Magnificent Mavericks* (China Lake, California: United States Naval Museum of Armament and Technology, 2007), 92.

[2] *Magnificent Mavericks*, 98.

[3] "Interview with Dr. William B. McLean: Recollections of the SIDEWINDER and WALLEYE Missile Programs," conducted by A.B. Christman and R.G. Douglas, Naval Weapons Center, November 16, 1973, 13.

The initial Sidewinder development team included (l-r) Ed. Swann, Lee Jagiello, team leader Dr. William B. McLean, Dr. Howard Wilcox, Dr. Walter LaBerge, Lt. Jack Christman.

of several hundred employees with a score of intermediate managers (branch and division heads), all reasonably expecting his time would be spent managing and leading them and taking care of their problems. Despite that, he was substantially clear in his determination "to act personally as project engineer" on Sidewinder. It was almost unprecedented that a Navy laboratory department head would dream of managing such a challenging project when he had substantial other responsibilities to perform and, theoretically, a number of senior technical personnel to whom he could reasonably assign such a managerial position.

If his technical responsibilities were complicated at this point in late 1950, they became even more so several years later when he was asked to manage the entire organization.

As the world moved further into the future and away from the devastating war that had enveloped it, valuable lessons learned in that conflict faded, even the fundamental ones of getting along and cooperating to a common purpose. Dr. L.T.E. Thompson (Dr. Tommy, to almost all the people who worked for and with him), the first NOTS technical director, had understood the necessity of military-civilian cooperation at a Navy laboratory to an extraordinary degree. Dr. Frederick W. Brown, who had succeeded him (at Thompson's behest), had inherited none of his predecessor's understanding of that requirement. Fortunately, for a time, his military counterpart was Captain Paul D. Stroop, whose affable nature and extreme enthusiasm for his assignment prompted him to overlook some of Brown's forays into his areas of responsibility. Unfortunately (for the station), in the fall of 1953, Stroop was selected for flag rank and posted quickly to a weapons position in Washington that required his expertise.[4]

Substantial volatility between CO and TD

Captain David B. Young succeeded Stroop as the sixth commanding officer of the Naval Ordnance Test Station, and he also had difficulties with the military-civilian relationship. (Given the environment in which he was educated, with the concept that the word of the officer in charge of a station or platform was law, that was perhaps not unreasonable. It became so at a Navy laboratory, particularly one managed by the Bureau of Ordnance.) The differences separating the station's two senior individuals quickly became insurmountable, and two former key figures of the organization, now members of the NOTS Advisory Board (formed by the groundwork of Thompson and first "launched" at a meeting in August 1949),[5] attempted to resolve the problems. Dr. Tommy made some suggestions that were ignored. Captain William Parsons, whose achievements were cited in Chapter 5 and included acting as weaponeer on the atomic bomb dropped on Hiroshima, had become the deputy chief of the Bureau of Ordnance. As such, he had substantial authority to direct various operations at NOTS. He attended the Advisory Board meeting in November 1953, where the volatile relationship of Brown and Young was discussed. He made it clear he would convince his boss to transfer Captain Young if the board would find another suitable job for Dr. Brown, which they did—a position directing the Bureau of Standards laboratories in Colorado. The board advised Brown in March 1954 that their report to the BuOrd chief would include the recommendation he be replaced; he resigned almost immediately and took the position in Colorado. (Captain Young would be requested to retire the following spring after a new BuOrd chief discussed the history of the conflict frankly with the Advisory Board.)[6]

Even before the technical director's job was vacant, key NOTS leaders, past

---

[4] *Magnificent Mavericks*, 282-3.
[5] *Magnificent Mavericks*, 120-123.
[6] *Magnificent Mavericks*, 369.

and present, had discussed the possibility of selecting Bill McLean as Brown's successor. With substantial Advisory Board support, the BuOrd chief offered him the job March 19, 1954, and he accepted, only to have the chief realize he had failed to take the appropriate official actions to fill a Public Law position.[7] He apologized and immediately set to work to rectify the situation; within a matter of months, Dr. William B. McLean was the third NOTS Technical Director.

In the interim, McLean was asked for his opinions on the operation of the station, particularly the military-civilian relationship (failure of which had cost his predecessor his job and would soon cost the commanding officer his). He provided a comparison of a military officer and a civilian scientist based upon the differences in their positional attitudes and training, noting that science required its practitioners to seek truth through experimentation and to delay a decision until that truth had been established reasonably well, while a military environment with its chain of command required those involved to act in accordance with principles well established but not necessarily the correct ones.[8] A congressional committee focusing on military-civilian relationships and how they affected Department of Defense research and development programs invited him to testify; his mailing a copy of his planned statement to a committee member prior to his testimony intensified interest. Following his testimony, and no doubt with other supporting input, the committee singled out the Bureau of Ordnance labs (NOTS and the Naval Ordnance Laboratory) as models for similar organizations to imitate.

Laboratory management

William B. McLean had spent most of the decade of the 1930s at the

---

[7] Several years after NOTS was established, Congress enacted Public Law 80-313, empowering the secretaries of War and Navy to establish the first executive-level federal positions (30 for the War Department, 15 for Navy). Two years later, "Public Law" positions increased to 400 under the Classification Act of 1949, which augmented the General Schedule by adding GS-16, 17 and 18 positions. These were generally scientific and professional positions in research and development requiring personnel with special qualifications. See: "Executive Manpower in the Federal Service," U.S. Civil Service Commission, September 1975, 1 & 43. As will be discussed in Volume II, the leadership positions at the Navy laboratories later were part of the Senior Executive Service.
[8] *Magnificent Mavericks*, 358.

California Institute of Technology, earning his bachelor's degree in 1935, his master's in 1937, and his Ph.D., studying under none other that Charles Lauritsen, in 1939. As noted elsewhere in this volume, if he had not moved to the University of Iowa for post-doctoral study and then to the Bureau of Standards during the war, Lauritsen undoubtedly would have involved him in Caltech's weapons development projects at what was basically the "founding" of the Naval Ordnance Test Station. McLean had decided opinions on how to operate in a laboratory environment, and was not hesitant to share them. Don Moore, a young engineer who crossed paths with the technical director early on and whom the TD would request often to pursue some new idea for him, described his style: "McLean, I think, was a brilliant organizational person. His idea was to take some good people, and then respect that there was more than one correct way to do anything."[9]

Moore, who acknowledged his division supported numerous McLean initiatives and who described him as an individual "totally dedicated to the welfare of the country," continued,

> … often, by design he'd try to get three or four people with different approaches, trying to find the weakness in his idea. If you don't expose yourself to your peers you will never find all the weaknesses… They will find weaknesses over a period of time and get rid of all the weak spots."[10]

Listening to the opinions of others, even (or perhaps especially) those who disagreed with him, was an important aspect of McLean's leadership. He recognized the people were the essence of a laboratory, and he treated them accordingly. Despite his title of technical director, he viewed his responsibilities as radically different than "directing," telling a national magazine reporter, "We have 4,800 civilian employees, and the ones in the technical organization work for me—as much as anyone ever works for anyone in a technical organization. Let's say I can protect them from being directed."[11]

He formed teams to pursue various aspects of projects, with some general direction, but without specific instructions, knowing several approaches developed independently increased the potential for finding an effective one or perhaps even several. He also understood people's desires to change jobs, change projects, seek

---

[9] Donald K. Moore, Naval Weapons Center interview S-185 conducted by Elizabeth Babcock, October 11, 1990, 24.
[10] Moore interview, 5.
[11] William B. McLean, "The Navy's Top Handyman," *Life* magazine, January 6, 1967, 31.

something new and different to do, and his support of that resulted in a positive for the work environment:

> [McLean] had the absolute right of transfer. If you were an engineer working somewhere and someone else on the base offered you a job, you could transfer no matter what your boss said, no matter what anyone said, you could transfer. What this meant was that branch heads and supervisors tended to try to treat their people well or otherwise they would lose them. It was a very simple thing, but it was genius because it turned out that people were treated very well and good people got recognized because everybody was trying to steal everybody else's people. It worked fine. It really did. He recognized very early that there had to be competition, so he would never allow a single department or group to be assigned the sole responsibility for something because he knew that they would get lazy.[12]

McLean also recognized the importance of effective administration coupled with infusion of new ideas, which meant, since he was generally the one with the ideas, that he required an alter ego to handle the administrative aspect of the effort. For a dozen years of McLean's tenure as TD at NOTS, Haskell G. "Hack" Wilson was that alter ego. As one of the staff put it succinctly, "Hack saw to it that things got done, and Bill saw to it that there were lots of things to do."[13] When McLean moved on from China Lake to head the Naval Undersea Warfare Center, Wilson assumed the NOTS/Naval Weapons Center TD leadership, and Doug Wilcox became McLean's new deputy in charge of getting things done.

Often substantially ahead of his time, possessed of an innate brilliance that often confounded his peers, and frequently cited with prestigious awards, McLean maintained appropriate respect for the station commanding officers and his superiors in government high places, such as the Bureau of Ordnance. At the same time, he expected those people in high places would recognize the importance of allowing the scientists to pursue their science without non-helpful meddling in the guise of bureaucratic necessity. Speaking about those principles (government functionaries staying out of the way of research scientists), McLean recalled,

> The charters of NOL [Naval Ordnance Laboratory] and NOTS were radical at the time they were written in that they gave joint responsibility to the Technical Director and the Commanding Officer. And they in essence directed the Commanding Officer to delegate the technical work to the Technical Director.[14]

---

[12] Tom Amlie, Naval Weapons Center interview, 4, quoted in Cliff Lawson, *History of the Navy at China Lake, California, Volume 4: The Station Comes of Age* (China Lake, California: United States Navy, Naval Air Warfare Center Weapons Division, 2017), 506.
[13] Dr. Pierre Saint-Amand, Naval Weapons Center interview S-21, 29-30.
[14] Dr. William B. McLean, Naval Weapons Center interview conducted by Albert B. Christman, July 1975, 4-5.

In other words, while the laboratories would be funded and administered by the Navy, and the assigned senior officers would provide appropriate leadership, the civilian technical people would run the science and technology part.

In his dealings with Navy bureaucracy, McLean avoided confrontation and accommodated the rules when their effect did not directly hurt the end product:

> We didn't have any strategy for Sidewinder as long as we kept the cost low…the problems came when the Chief of the Bureau of Ordnance wanted to fund it. His guided missile section, Re-9, didn't want to fund it. So, he said 'Alright, if you don't want to fund it, we'll call it a fuze and turn it over Re-2,' who were the fuze group for the Bureau of Ordnance. They funded it, so it came out initially as a fuze, one of whose purposes was to move the rocket closer to the target.[15]

As was appropriate, McLean set the style of leadership, scientific exploration, and practical engineering at NOTS during that period, a time of unprecedented achievement.[16] (It is important to recognize McLean displayed a seemingly uncanny ability to recognize leadership qualities in others, including those who did not understand it in themselves. We will discuss several pertinent examples later.) While living and working at NOTS in China Lake, McLean also directed the work in Pasadena, Morris Dam, San Clemente Island, and Long Beach, collectively termed the "Pasadena Annex"[17] (a term Pasadena employees considered negative, if not derogatory).

Sidewinder

In 1949, when Bill McLean first proposed a heat-seeking air-to-air combat missile, attention in other laboratories was focused on radar-guided ordnance. Radar was a rapidly improving technology (helped in part by R&D on the subject at the Navy Electronics Laboratory in San Diego). The Air Force in particular felt a system by which radar locked onto a target and guided a missile offered the best possibility for success, and indeed in air-to-ground combat, against stationary or slow-moving targets, early radar testing had shown promise. In response, senior Air Force management provided substantial funding to a contractor for the development of Falcon, "a well-funded problem-plagued program, to which

---

[15] William B. McLean interview by Christman and Douglas, 8.

[16] W.H. Pickering, *William B. McLean, 1914–1976, A Biographical Memoir*. (Washington, D.C.: National Academy of Sciences, 1985), 402.

[17] "Basic Information about NOTS," U.S. Naval Ordnance Test Station, China Lake and Pasadena, California, TS/62/168, 1962, 2.

Hughes [Aircraft] devoted vast material resources and labor."[18] Aircraft designers equipped modern jets with radar for several purposes, so why not add weapons guidance capability?

In his early section head job, McLean had developed, for the first time, quantitative methods for assessing the variables influencing the performance of a fire control system. With those in hand, he realized improvement in fire control systems quickly would make them so intricate as to be unworkable. If he could identify some property of the target itself to guide the air-to-air missile, the fire control system could be embedded in the missile, rather than on the launching aircraft. The blazing heat of a jet's exhaust presented itself as a possibility.

The idea of a heat-seeking missile was promising in theory, because such a weapon could guide itself to its target independently from the moment of launch. But nobody had come close to creating an "intelligent" system that was small enough to be mounted on a rocket, accurate enough to discern the heat of a jet engine, and responsive enough to guide a missile at flight speed. Moreover, such a technology would have to be robust enough to survive jet acceleration, air pressure, and maneuvering g-forces; simple enough to be reliable in the field; and cheap enough to supply weapons in large numbers.

NOTS engineers had a track record of developing reliable rocket propulsion and detonation components; if they could pull it off, the heat-seeking and guidance systems would make Sidewinder an unmatched aerial weapon.

The NOTS team devised a simple heat-seeking system based on the patent McLean had been issued: a rotating mirror in the transparent head of the weapon reflected infrared (heat) radiation onto a lead sulfide photocell. The mirror moved servo units that guided canards (front-mounted fins) on the exterior of the missile. By tracking jet engine exhaust heat, the system guided the missile to the target.

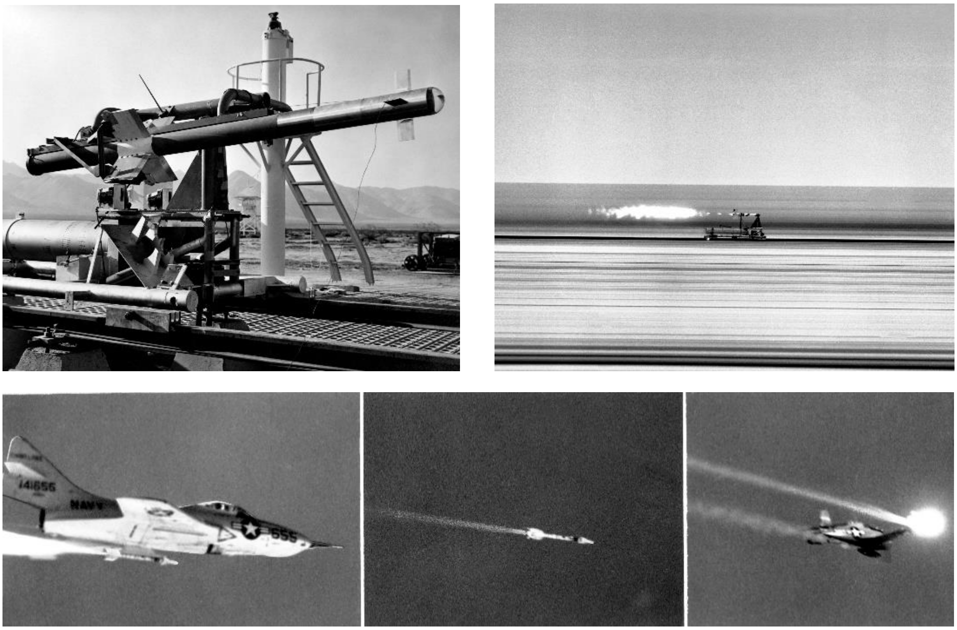
The technical problem of guidance, said McLean, was fraught with variables:

> We found the biggest error was the motion of the target after you fired. And there is just no way to correct that in the fire control system. You could make the fire control system for the rocket perfect and get out all the errors that occur, like the wind stream deflection and the wings deflecting under [g-forces]…but the biggest one is what the target does after you fire.[19]

---

[18] *Magnificent Mavericks*, 397.

[19] William B. McLean interview by Christman and Douglas, 2.



The Supersonic Naval Ordnance Research Track (SNORT) provided the venue for the first "free flight" of Sidewinder (top left), as the missile streaked down the track (right). In the air as well as on tracks, Sidewinder demonstrated its effectiveness (bottom sequence).

In other words, how to release a missile that will pursue a moving, turning, diving, or climbing jet aircraft? The answer was to put the heat-seeking element onto a stable gyroscopic mount in the front of the missile. McLean recalled:

> We had to put in a gyro, and experience on the Bat missile [an earlier program] taught us that the gyro ought to be free and not geared to the airframe, so that when you turn the airframe the gyro can sit still in space. By working on that problem, we came up with the technique of putting a coil around the spinning magnet and precessing [changing the orientation of the rotational access] the gyro relative to the target signal without having to resolve the missile coordinates. The gyro could then track independently, regardless of what the missile was doing.[20]

In typical McLean fashion, several teams of engineers were assigned to develop different versions of heat-seeking elements. Several seekers were developed, with the most promising (based on McLean's assessment early in the development) working perfectly at a long distance from the target. As the distance decreased, however, the gyro began to wobble, eventually to the point the seeker

[20] McLean interview by Christman and Douglas, 2.

lost contact. The wobbling motion, technically called nutation, in Sidewinder's gyro guidance system was solved based on a common household applicance. When a washing machine is in the spin cycle, a load of wet clothes should unbalance the washer. Appliance makers countered that by using a liquid-filled damper to eliminate the potential wobble. NOTS personnel had previously installed nutation dampers on spin-stabilized satellites. A similar damper with plastic tubing and mercury in an annular raceway solved Sidewinder's nutation problem. In his Naval Weapons Center interview, Don Moore, after citing the satellite example, gave the credit for the washing machine connection to McLean. Elizabeth Babcock, who conducted that interview, provides a more credible account of the discovery, attributing it to technician Don Stewart based on a discussion of the project by (later China Lake TD) Tom Amlie.[21]

There is no doubt Sidewinder as a concept was entirely McLean's (although there was some serious patent litigation on the subject at that time).[22] There were times, however, such as the washing machine tale above, when questions about claims were in order: "China Lake legend holds that McLean built Sidewinder in his garage, but those who worked with him in those early days remember his almost-constant presence in the well-equipped laboratories and machine shops of Michelson Lab, within half a mile of his home."[23]

While he might have had an inspirational thought and "tinkered" for a while in his garage workshop, it was only a matter of hours or a few days before the inspiration was transferred to a Michelson machine shop for formal prosecution.

After a substantial amount of development, refinement, and surmounting of problems, the weapon was taken out to the range to see how it would perform in tracking an actual moving target. Unfortunately, the target survived the first dozen firing tests of Sidewinder. In 1952, a decorated Korean War fighter pilot, Lieutenant Walter M. Schirra, Jr., launched the missile from his aircraft at a drone, and it missed. On another test run, a Sidewinder doubled back and headed toward Schirra, almost depriving the Navy of one of its most accomplished future

---

[21] *Magnificent Mavericks*, 302. Stewart also developed a replacement for the Sidewinder's ball gyro gimbal "of which McLean had been so proud," employing a more complex device with eight parts compared to the original two. Contrary to expectations based on his penchant for the simple vice the complex, McLean, who realized the pressing need to replace the gimbal, was delighted. (*Magnificent Mavericks*, 392).]

[22] *Magnificent Mavericks*, 208-209.

[23] *Magnificent Mavericks*, 101.

astronauts.[24] It was an inauspicious beginning, but on February 17, 1954, a Sidewinder destroyed a QB-17 drone, inaugurating a sixty-year (and counting) winning streak.[25]

Sidewinder's performance was so revolutionary it forced an evolution in air-to-air combat tactics, which had remained essentially the same since British and German pilots battled in biplanes in World War I. Fighters had always closed with each other and pursued opponents with maneuver and speed, firing bullets or cannon shells at short range. Jets equipped with Sidewinder missiles, on the other hand, detected enemy aircraft with radar and stood off at a distance, launching missiles that would take over the job. Eventually, systems designed to detect similar missiles, and evasion techniques like releasing flares, became defensive doctrine.

Operational in 1956

Sidewinder went into operational use in 1956 and was quickly adopted by America's allies. Its first kill was recorded September 24, 1958, when a Republic of China F86-F brought down a Communist Chinese MiG-17. At home, the missile was deployed on Navy, Marine, and Air Force fighter jets, which a decade later used it to win more victories in the skies over Vietnam than any other weapon. The current version (in 2015), designated AIM-9X (Air Intercept Missile) and manufactured by Raytheon, entered service in 2003. Through many improvements in electronics, sensors, propellants, and virtually every other component, the essential system—an infrared-sensitive "eye" guiding a fast-moving and highly maneuverable missile—remains true to the concepts of McLean's team at China Lake.[26] Succinctly summarizing its advantages, a 1963 hand-out to a huge crowd

---

[24] Schirra went on to become the only astronaut to fly Mercury, Gemini, and Apollo missions.

[25] Preston Lerner, "Sidewinder: The missile that has rattled enemy pilots since 1958," *Air & Space Magazine*, November 2010. Also, "Sidewinder Missile Approaches Sixty," Defense Media Network, http://www.defensemedianetwork.com/stories/successful-sidewinder-approaches-sixty/, accessed March 20, 2015.

[26] "AIM-9 Sidewinder," U.S. Naval Museum of Armament & Technology, http://www.chinalakemuseum.org/exhibits/sidewinder.shtml, accessed March 21, 2015.

of visitors that included President Kennedy advised,

> The Sidewinder is an inexpensive but extremely reliable missile. Its effectiveness is due largely to the fact that it has few moving parts and no more electronic components than an ordinary radio. Personnel who are responsible for assembling and maintaining it require no special training.[27]

Several years after it became operational, McLean spoke at a conference dedicated to the management of advanced technology. In his opening remarks, he expressed his sentiments that his place on the program following two speakers on the Polaris missile, for which his organization was also significantly responsible, had more to do with "providing contrast" than grouping talks on weapon systems:

> SIDEWINDER and POLARIS [sic] are certainly quite different—in size of the job, the amount of money involved, and in the kinds of management techniques employed… Our prime motivation was to avoid the construction of the Aircraft Fire Control System Mk 8 .… We also believed there was a good chance that this missile could be made to work as simply [as] and more effectively than the fire control system for unguided rockets… The management of SIDEWINDER was relatively easy because of the organizational setup. We had a rather small number of good people who were highly dedicated to getting the job done and who worked closely together so that they had a good appreciation of the over-all problems.[28]

For his inspiration in pursuing a concept avoided by almost everyone else and for his leadership of the effort even while he was directing the entire organization, McLean received substantial recognition. In 1956, the Chief of Naval Operations presented him the maximum monetary award for a civil servant at the time: $25,000. (To put that into perspective, during John F. Kennedy's visit in 1963, the President asked the NOTS station commander why McLean, who made "a mere $20,000 a year," continued working for the service. He was advised it was because he was dedicated to the Navy.)

In January 1958, President Dwight D. Eisenhower presented McLean the gold medal for Exceptionally Meritorious Civilian Service. His alma mater, Caltech, accorded him its Distinguished Alumnus Award, and he was one of the four first-year recipients of the NOTS L.T.E. Thompson Award. He was in very good company: the others included "Dr. Tommy" himself, and Rear Admiral (later Vice Admiral) Levering Smith, who after serving as Explosives Department head and associate technical director managed the Navy's Special Projects Office,

---

[27] "Aerial Weapons To be Used in the Demonstration," hand-out at China Lake open house, June 7, 1963, 1.

[28] Dr. William B. McLean, "The Sidewinder Missile Program," presented at the National Advanced Technology Management Conference in Seattle, Washington, September 5, 1962.

providing technical leadership for the Polaris and Poseidon fleet ballistic missile programs.

President Eisenhower honors Dr. William B. McLean for Exceptionally Meritorious Civilian Service.

An unlikely facility named "SNORT"

After several seasons of failures, the Wright Brothers succeeded in powering an "aircraft" into the skies over North Carolina. One of the major contributing factors to the success was a wind tunnel.[29] As noted in the reference, the two obvious approaches to subjecting a flying object to the laws of aerodynamics are to move a test vehicle at the appropriate velocity through the air, or to station the vehicle and simulate wind blowing past it at the desired velocity (the basic premise of the wind tunnel). As early as 1945, NOTS personnel, using the former (and generally more difficult) approach, had constructed the equivalent of railroad tracks, and, using the actual weapon's motor, "launched" rockets down the tracks

[29] Donald D. Baals and William R. Corliss, Wind Tunnels of NASA, viewed October 5, 2017 at https://www.grc.nasa.gov/www/k-12/WindTunnel/history.html.

at high speed.[30] The first track was a set of rails 1,500 feet long, employed for testing early rockets "as well as for tests of warhead and fuze impact at free-flight speeds." The following year, a nearly three-mile-long track was constructed using two standard-gauge rails.

Although these and several other tracks provided valuable information for weapons designers and testers, none of the tracks was long enough to accumulate sufficient data to satisfy test conductors. To remedy that, NOTS developed and forwarded to the Bureau of Ordnance specifications for an appropriately named "Long Track" (twenty-five miles long!) in November 1947. After due consideration, the bureau authorized the station to initiate feasibility studies on a less costly eleven-mile track.

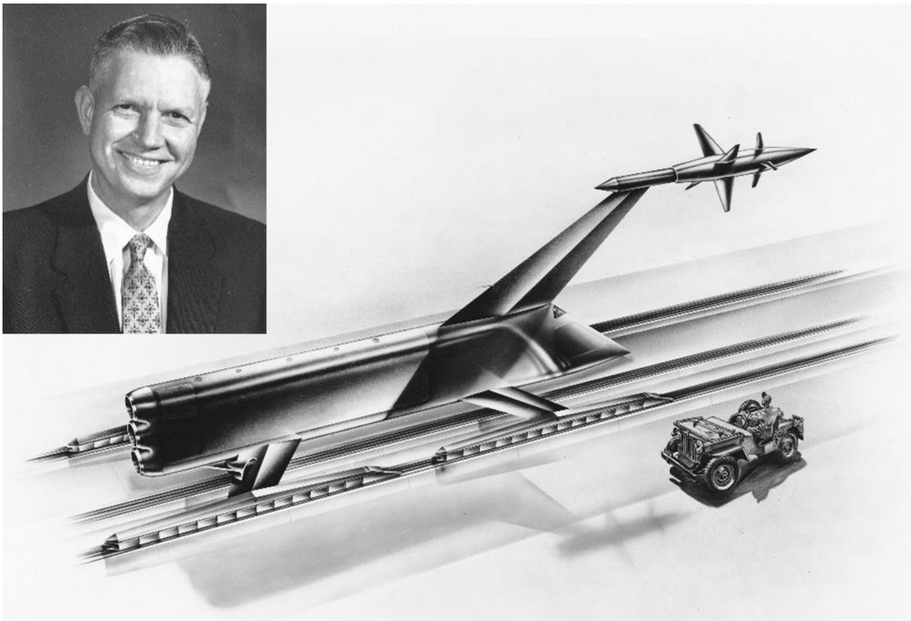
Planning progressed on the project and in April 1949 the proposed name gained BuOrd approval: Supersonic Naval Ordnance Research Track (SNORT). Interestingly, the Underwater Ordnance Department (UOD) in Pasadena was tasked with designing the track and its support equipment. A little more than two years after after his impressive Variable Angle Launcher was dedicated at Morris Dam, James Jennison, who headed UOD's Development Engineering Division, was selected to lead the project.

Bids were solicited from appropriate contractors, but sticker shock at those bids chopped substantially more length off the track, until construction began on a 4.1-mile version on January 14, 1952. Tons of concrete (poured in a fashion to resist horizontal and vertical stress) and more tons of heavy crane rail, which was laid in fifty-foot lengths to minimize the number of joints, formed the foundation of the track. While contractors handled that work, Jennison and his crew worked on design of the test sled and the all-important water and sand brakes. The first run on the track was made November 18, 1953, and, by the following February, it was clear the project was a success.[31]

The first public demonstration of the track (one of the major attractions for years afterward at the station's traditional Armed Forces Day open house) occurred in late March 1954. It is highly probable the audience of 1,300 included Jennison's Underwater Ordnance Department head Bill Steel and fellow UOD division head Doug Wilcox, who would succeed Steel in a couple of years.

---

[30] *Magnificent Mavericks*, 242-4.
[31] *Magnificent Mavericks*, 247.



Artist's conception of the Supersonic Naval Ordnance Research Ttrack designed by Jim Jennison (inset).

Douglas John Wilcox

A second-year student at Cornell University in his native New York in the early 1940s, Wilcox left school shortly after the outbreak of World War II. Entering the Army as a private, he returned to Cornell three years later as a captain. He completed his mechanical engineering studies in February 1948 and a month later was a Junior Professional Assistant at the NOTS Pasadena Annex.[32] Although he was a competent engineer, his real talent resided in management, no doubt triggered and certainly strengthened by his time in uniform. After initial technical

[32] The station's progressive Professional Development Program, which originated at Pasadena, is discussed later in this chapter. That program began with Wilcox's class in 1948 and continued with the NOTS successors up to the present Naval Information Warfare Center Pacific. It represents the annual lifeblood infusion of new scientific and engineering talent to the Center.

work on combustion and detonation of gases and development of a high-velocity launching gun used at Morris Dam, he quickly became a national authority on high-speed underwater rockets and almost as quickly a division head. His responsibilities in the latter position included oversight management of the test ranges at Morris Dam, Long Beach, and San Clemente Island. In June 1956, a mere eight years after arriving in Pasadena and less than thirty-five years of age at the time, he was selected to head the Underwater Ordnance Department.[33]

During his division head assignment, Wilcox supervised development of the Rocket-Assisted Torpedo (discussed below). The technology behind that evolved into a new, more capable weapon system, the Anti-Submarine Rocket (ASROC). In May 1956, Wilcox was placed in charge of the ASROC program; the following month McLean selected him to head UOD. (Like his boss, he was asked to run a department of hundreds of scientists and engineers and manage a major development program simultaneously.) The young Pasadena department head/program manager did not disappoint his technical director. He put together a dynamic group of division heads to perform the in-house technical work, while he managed the huge team—1,800 people at one time from thirty government and industrial organizations—and worked to keep headquarters and the sponsoring Bureau of Ordnance) apprised and satisfied. As an integral part of that, he drove the 300-mile round trip from Pasadena to Inyokern weekly.

His efforts did not go unnoticed. In late 1957, Doug Wilcox of Pasadena and the unrelated Dr. Howard Wilcox of China Lake—who worked on the Manhattan Project, Sidewinder, and ASROC—were both nominated for the prestigious Washington, D.C. Junior Chamber of Commerce Arthur S. Flemming Award; Doug Wilcox was one of the ten awardees in February 1959. In the interim, he had received a Sustained Superior Performance Award in 1958,[34] which would be followed up with the station's highest honor, the L.T.E. Thompson Award, in 1961. A general organizational hand-out the following year included a description of the award and identified him not only as the UOD head, but also as the NOTS Assistant Technical Director for Development (Weapon Systems).[35]

Doug Wilcox presented an interesting counterpoint to McLean, whom he obviously admired and highly respected. Clearly both were exceptional managers,

[33] NOTS *Rocketeer*, June 8, 1956, 3.
[34] Naval Ordnance Test Station *Rocketeer*, July 11, 1958.
[35] "Basic Information About NOTS, 1962," 27.

Douglas J. Wilcox

but the latter's hands-on "tinkering" and hands-off management style contrasted sharply with his subordinate's traditional top-down philosophy. Don Moore, who for months spent one day a week in Pasadena as Wilcox spent one at China Lake, recalled the Pasadena organization employed "a more classical management style than you would find anywhere in China Lake. Very, very strong chain of command… There was a single personality there…Doug Wilcox and Wally Hicks had to say OK or nobody would do anything."[36]

(Wallace E. Hicks was Wilcox's technical alter ego, keeping close watch on scientific and engineering development while Wilcox concentrated on relations with China Lake, Washington, and industry partners.)

While Wilcox for all practical purposes ceased being an engineer and became a manager, McLean frequently haunted the extensive machine shop of Michelson Lab to work some new idea into a physical device.

One point of solid agreement between the two laboratory leaders was the critical necessity of nurturing talent. As Wilcox stated in an interview a year after

[36] Don Moore interview, 23.

the creation of the Naval Ocean Systems Center, where he served for almost a decade in the number two position:

> To me the lab belongs to young people. We have to feature them. We have to give them a chance to make some mistakes… I feel everybody should make one big botch per year and if you don't make one big botch per year you're probably not sticking your neck out on some area where you should.[37]

Shortly after he retired in 1986, Wilcox was presented his third Navy Superior Civilian Service Award, rationale for which included his staunch support of what was then called the New Professional program.

Wilcox also had an appreciation of his many contractors not often found in government officials, especially those working a large program, regarding them as people with the same interests and goals rather than working units under contract: "If contractors 'are committed to the same goals that NOTS wants to achieve, there is a good chance that the program will move ahead in the right direction.'"[38]

Despite their managerial differences, Wilcox by hard work and determination earned McLean's confidence, and he was a willing student of McLean's principles, if not his hands-on methods. For example, Wilcox said of McLean's habit of solving component problems by eliminating the component,

> I talked to him one day about the problem of connectors in ASROC… He said, 'Well, don't put any connectors in it. I mean, if you've got a connector problem, eliminate the connector….' So in the ASROC missile we hard-soldered wired in all the connections at the factory. You know what? We never had a connector failure…. it is amazing how many times you think you need something or some piece of equipment when in fact if you do it a little bit differently you avoid the problem.[39]

Torpedoes

The debacle of the Mark 13 torpedo at the battle of Midway was discussed in Chapter 4. Although the efforts of Jim Jennison and others working at Morris Dam had developed a "fix" that dramatically improved its performance, the post-WWII Navy was not particularly sold on torpedoes, having seen the spectacular effects of rockets and atomic bombs. To determine the future direction of torpedo

---

[37] Douglas Wilcox, Director of Navy Laboratories History Study interview conducted by A.B. Christman, March 13, 1978, 6.
[38] *Magnificent Mavericks*, 452.
[39] Doug Wilcox, Christman interview, 14.

development, the Bureau of Ordnance directed a study on the subject. Asked to head it was Dr. Gaylord P. Harnwell. (The reader will perhaps recall that during World War II Dr. Harnwell directed the University of California Division of War Research on Point Loma. Following the war, in addition to serving as president of the University of Pennsylvania, Harnwell had worked with the Point Loma lab on the major antenna study in 1946. He would return later to participate in a joint NEL-National Academy of Sciences study of seafloor mine countermeasures.)

The outcome, generally referred to as the Harnwell Report, provided recommendations on countermeasures, standardization, targets, evaluation, and field testing, as well as on reorganization of the Navy torpedo RDT&E program.[40] The principal point was a proposal to centralize all torpedo development at one organization. At the time, there were four, including NOTS Pasadena.

To minimize expected negative reaction to the recommendation, Harnwell's group proposed the four labs themselves agree on a consolidation plan. The resulting lab committee met on a periodic basis, agreeing first to determine torpedo development priorities, and, second, to decide which lab would pursue development. The lab committee report convinced BuOrd to reject the Harnwell one-lab concept, and to continue torpedo development in three of them: Newport (the Navy's very first torpedo developer) would be responsible for surface ship- and submarine-launched torpedoes; Penn State would continue its existing assigned work; and NOTS would be the technical director for air-launched torpedoes—Mark 27, 32, 41, 42, and the Mark 24 passive-acoustic homing mine. The Pasadena Annex was already working on Mark 32 and 42.

The Mark 32, an acoustic homing torpedo, was built late in World War II, but after the fifty that were completed underwent initial testing, they were put on the shelf. When the Korean War began, "there was this realization that we didn't have anything in the Fleet that hadn't been there before World War II, with regard to modern torpedoes… And so they resurrected the Mark 32 program."[41]

Other than the WWII effort previously described on the Mark 13, the major torpedo work at the Pasadena Annex after the war involved propulsion systems and some propeller design. With the renewed interest in torpedoes, the annex assumed a much greater involvement in their development, typically acting in

---

[40] *Magnificent Mavericks*, 337-338.
[41] Mort Heinrich, SSC Pacific oral history interview conducted by Tom LaPuzza, June 20, 2012, 5.

partnership with industry contractors. In the case of the Mark 32, electronics manufacturer Philco was contracted to modernize the electronics, and Pasadena was assigned to test the upgrades.

Mort Heinrich, who would spend decades designing and managing design of torpedoes at the lab, explained,

> The electronics that were used in the torpedo originally were parts… of railroad signals and relays. Nothing was hermetically sealed. The vacuum tubes hadn't been hardened in any way… And the idea was to bring it up to 1950 standards so it could be manufactured. And so that's how the Center started in… I'll call it lightweight torpedoes. And I'm sure we had a torpedo that ran very slow… but at that time, submarines didn't run very fast either.[42]

Heinrich was hired as testing began, and as lab engineers had done during the war, he and his associates jury-rigged equipment to conduct their tests. They built a wooden slide on an old landing craft and slid torpedoes into the water to run against an echo repeater simulating a submarine. The torpedo's transducers measured water pressure and acoustics data, recording that data by scratching carbon off celluloid or by exposing long rolls of film. At the end of a day's testing, Heinrich explained, "We had little boxes… with about sixty feet of tape that would record eight minutes of data, so you could tell what happened with the torpedo."[43]

The Mark 32 Mod 2 ASW torpedo that resulted from the effort "went into the Fleet and they had what they called a 'catapult launcher.' The torpedo was athwartships and it went [sound effect to represent throwing or tossing] and flipped it."[44]

Its service life was fairly brief (early to mid-1950s) but it signaled the advent of torpedoes with advanced postwar electronics.[45]

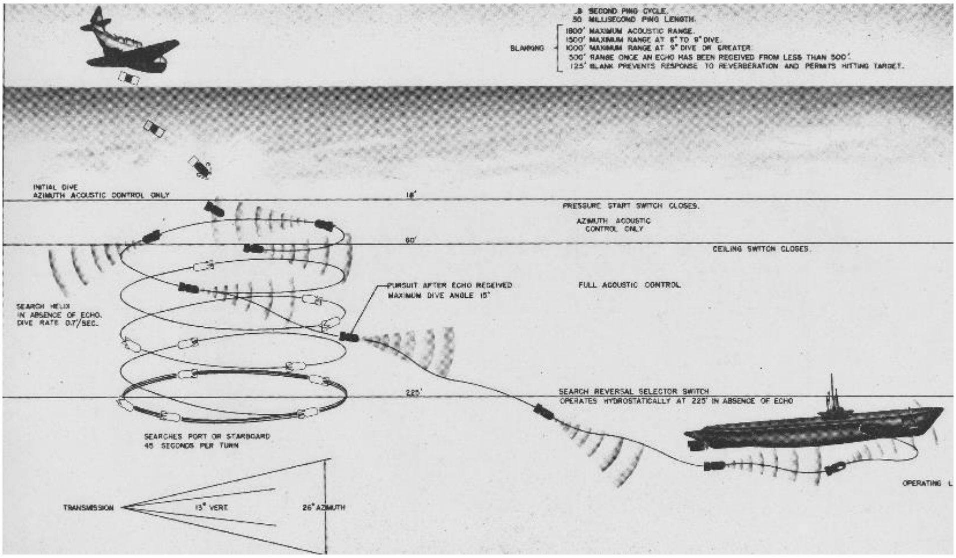
With that successful work behind it, the Pasadena group launched into the torpedo development business. It was generally reactive, since as a performance standard a torpedo must run fifty percent faster than its submarine target in order to catch it, taking into account its evasion capability. As the 1950s moved into the

---

[42] Mort Heinrich, SSC Pacific contractor interview, December 16, 2014, 3.
[43] Mort Heinrich, SSC Pacific contractor interview, 4.
[44] Mort Heinrich SSC Pacific interview, 11. "Athwartships" is a nautical term designating something that is perpendicular to the fore-to-aft center line of a ship.
[45] "United States of America Torpedoes since World War II," http://www.navweaps.com/Weapons/WTUS_PostWWII.htm, accessed January 6, 2015.

‘60s, the U.S. and the Soviet Union played off each other, both building faster submarines while simultaneously countering the other’s with faster torpedoes.

The Mark 32 had been designed originally to attack a German WWII diesel sub that could steam eight knots; thus, the torpedo had a speed of twelve knots.



Immediate post-World War II torpedo efforts by NOTS Pasadena centered on the Mark 32 torpedo, development of which had begun during the war. The top figure is a representation of the torpedo’s programmed search technique. Left photo shows siderail launch of the weapon.

The next generation of potential enemy undersea vessels could steam at eighteen knots, too fast for both the Mark 32 and the Mark 43. Heinrich related,

> So that's where the Mark 44 had a requirement for thirty knots. By that time, we had developed the Albacore nuclear submarine and they were looking at speeds of thirty knots… And so that's where the requirement then became—they picked the number forty-six knots as the next step… So each time it was in anticipation—and the Russians were great at that—of faster.[46]

And there were other considerations as well in the torpedo versus submarine competition, including depth capability and weapon delivery options. For example, the advent of helicopters in tactical Navy operations, which could reasonably deliver torpedoes for attack purposes, established a torpedo weight limit which the Mark 32 exceeded. The Bureau of Ordnance set a requirement for development of a lightweight torpedo under the EX-2 program.[47]

Somewhat coincident with the work on EX-2 described below, a contractor offered a privately developed torpedo to the Navy. NOTS Pasadena was tasked with technical direction for the development of this, the first lightweight ASW torpedo capable of launch from helicopters and fixed-wing aircraft as well as surface ships.[48] Pasadena designers solved a key vulnerability—the lightweight torpedo's fragility on impact with the water—by devising a protective clamshell air brake designed to be jettisoned at the moment the torpedo entered the ocean.[49] It became the Mark 43, introduced into the fleet in the early 1950s.

The Bureau of Ordnance, understanding the Navy's two current weapons—the Mark 32 and Mark 43—were unable in terms of speed to counter subs emerging from Soviet yards, tasked NOTS Pasadena with design and development of (experimental) torpedo EX-2A. General Electric was contracted

---

[46] Mort Heinrich, SSC Pacific interview, 19. In point of fact USS Albacore (AGSS-569) was still conventionally powered by batteries; its increased speed resulted from a unique hull design and a single, five-bladed propeller.

[47] Heinrich in his SSC Pacific interview explained the numbering protocol for torpedoes, stating various requesters were given new Mark numbers (in the 30s and 40s) in rapid succession, sometimes for devices that weren't actually torpedoes. In the mid-Mark 40s, that practice stopped, and "EX" terminology was used until the device became an actual torpedo under development. With significant upgrades, the number was retained and the "modification" was noted: Mark 46, for example, had at least five notable improvements, all of which were classified as Mark 46 Mod 1…Mod 5, rather than Mark 47.

[48] E.W. Jolie, *A Brief History of U.S. Navy Torpedo Development* (Naval Underwater Systems Center, 1 May 1978), 163.

[49] *Magnificent Mavericks*, 348.

to design the EX-2B. Despite the fact it was one of the two parties involved in the competition, Pasadena was given the responsibility to evaluate both torpedoes.

According to Mort Heinrich, Pasadena's EX-2A had a propulsion system developed by the Research Department, two batteries—a primary battery for war shot use and a nickel cadmium rechargeable battery for exercise testing, a small counter-rotating electric motor, and a guidance system from another department. The electronics were a version of the same acoustic system used in the Mark 37.

Twenty-five each of the two devices resulting from the competition were shipped to Key West, Florida, for a run-off between Navy and contractor. Asked who won, Heinrich said, "Numerically, it was a tie, if you just used pure numbers."

As the decision authority, BuOrd gave the nod to industry, as paraphrased by Heinrich:

> 'We have selected the EX-2B to be developed… However, the EX-2B was now going to be called the Mark 44… The Mark 44 now has to be modified to work in this new rocket system we're developing called ASROC [Anti-Submarine Rocket]. And NOTS, you are going to be the program manager, the Navy technical director. GE will do the details.'[50]

With that, Heinrich became engineering manager for the new weapon, a lightweight ASW torpedo capable of ship and air launch, with the added feature of a seawater-activated battery. The weapon also had credible improvements over the Mark 43 in terms of speed, acoustic homing abilities, and warhead size. Also powered by an electric motor, the 425-pound Mark 44 became the NATO standard lightweight torpedo. Its electric propulsion gave it a top speed of thirty knots and a range of 6,000 yards. The weapon was first deployed in 1957. It would remain the fleet's standard ASW torpedo for a decade, until replaced by the Mark 46.

Hydrodynamic simulator

The Navy laboratory in San Diego, with its contract partner the University of California Division of War Research, had expended significant effort during WWII developing various methodologies for locating submarines. To evaluate their developments, a significant number of U.S. submarines were employed as

[50] Mort Heinrich, SSC Pacific interview, 14.

"targets" for testing the latest refinements in sonar. The underwater weapons personnel at the Navy laboratory in Pasadena could not expect similar accessibility to submarine "targets" for testing highly explosive weapons. Instead, various underwater sound sources were used, along with an ingenious device powered by one of the very first computers employed by the Navy.

Work on the hydrodynamic simulator began while General Tire and Rubber was still administering the contract to manage former California Institute of Technology war-time facilities in Pasadena. The project was completed a month before the contract ended, and "Pasadena scientists used the simulator to subject full-scale torpedoes to conditions simulating those encountered in sea runs."[51]

Employing a Reeves Electronic Analog Computer, one of the first large-scale machines, Pasadena scientists and engineers were able to analyze the motion of a torpedo in three dimensions as it tracked a "target," which was simulated by the computer. Thus, at great savings in time, money, and trips to the sea range off Long Beach, they were able to study the control and guidance systems of the torpedoes they were designing for flaws and correct them before the weapons ever left the machine shop. Although sea tests were a necessity, the simulator allowed scores and even hundreds of "dry runs" and closely monitored hydrodynamic tests that drastically reduced the number required at sea. The simulator itself was continually upgraded and refined over the years to serve the torpedo development effort.

Weapon delivery rockets

For reasons mentioned in the course of this narrative, personnel at China Lake tended to develop rockets and missiles of various descriptions delivered from the air, while employees at the Pasadena Annex concentrated on underwater weapons. It was in fact policy that it should be so: "The [NOTS] Research Board decided that underwater work should be centralized in Pasadena, which had the technical expertise for that work as well as proximity to underwater testing facilities."[52]

Several developments that gained national headlines when made public were products of the two NOTS locations working together and marrying their areas of

[51] *Magnificent Mavericks*, 69.
[52] *Magnificent Mavericks*, 75.

expertise, beginning with an early post-war device called Weapon Able, or Weapon A. It was an outgrowth of work pursued by Caltech during the war.

Chapter 2 of this history included a brief description of early U.S. Navy (and other) efforts to develop and improve torpedoes, self-powered weapons designed for launch from a surface ship or a submarine (and later from aircraft as well) with the intent of attacking and sinking another surface ship or submarine. Also described previously was the adoption of British technology—the Hedgehog—to fashion a lightweight weapon system for yachts and other small craft pressed into service early in World War II to support the campaign against German U-boats. Designed to propel depth charges some distance from the launching vessel, the charges would sink and then explode at some predetermined depth with the hope of inflicting damage on an underwater vessel. The launcher for that system was given the popular title of Mousetrap. (Although a few accounts term the weapon "Mousetrap" as well, it's clear from the China Lake histories the weapon was an anti-submarine rocket, which was Mousetrap-launched.) Work on the Mousetrap launcher and/or its payload was conducted both by California Institute of Technology in Pasadena and the Navy Radio and Sound Laboratory in San Diego.

Shortly after war's end, the Navy Bureau of Ordnance defined a requirement for a rocket-propelled ASW weapon to be launched from a surface ship at long range under sonar direction. Faced with BuOrd specifications calling for a 12.75-inch warhead but building on NOTS' reliable 5.25-inch rocket-launching platform, station designers fashioned a weapon, the ungainly shape of which earned it the graphic nicknames "flying milk bottle" and "potato masher."[53] Significant to design and development was the pioneering use of aluminum and glass-reinforced plastic in the body of the device. The initial instantiation of Weapon A could throw a 250-pound depth charge as far as 800 yards from the deck of a warship. An improved, longer-range version (2,400 yards) was released to the fleet in 1956 and remained in the Navy's weapons inventory until 1969.

With Pasadena focus on torpedoes, the next joint effort with headquarters was a weapon duo called the Rocket-Assisted Torpedo (RAT). This was a similar and

---

[53] *Magnificent Mavericks* (page 27) states, "The station started the project in mid-1946, with notable support from Caltech people and facilities at Pasadena," indicating China Lake leadership and only support from Pasadena. The NOSC history *(Fifty Years of Research and Development on Point Loma, 1940-1990*, 33) says it was developed at Pasadena: "Working with the Naval Ordnance Laboratory in White Oak, Maryland, NOTS Pasadena developed Weapon A within 3.5 years."

yet substantially different device than a Mousetrap-launched weapon or a Weapon A, in that the rocket for the initial boost to gain distance from the attack ship was more or less the same, but the weapon was now a torpedo. Rather than merely sinking and exploding after rocket boost, the torpedo was equipped with a sonar to reacquire and direct it to the target, and a propulsion system to get it there.

The intention was to launch the motor-driven rocket from a surface ship into the vicinity of a submarine detected some distance away. The dual value of that was increasing by many square miles the surface ship's attack capability, while at the same time substantially decreasing the capability of the submarine to launch its own weapons first. Perched on the rocket's business (forward) end was a lightweight torpedo. At a critical time determined by the designer, the rocket would detach in the air and the torpedo, slowed by a parachute, would enter the water as if it had been launched from an aircraft. The torpedo would reacquire the target with its on-board sonar and chase down the submarine. Equipped with one of the ubiquitous fuzes for which China Lake was justly regarded as expert, the torpedo would explode at the appropriate distance to cripple or destroy the sub.

There were of course serious technical problems to overcome, chief among them protecting the blunt nose of the torpedo from impact with the ocean at the high velocity caused by a combination of rocket thrust and gravity. NOTS engineers designed a hemispherical nose cap of shock-absorbing cellular cellulose acetate, with an axial hole drilled through its center. Water entering the hole upon impact shattered the nose cap, which would absorb a significant amount of the impact shock. The cap was tested successfully both at the Long Beach Sea Range and at Morris Dam, and the development team declared success.[54]

RAT was revealed to the public at a Pasadena news conference on February 10, 1958, generating headlines in papers across the country.[55] After a front-page article the following Friday reporting on the news conference and on the weapon itself, the NOTS *Rocketeer* followed up four weeks later with a special four-page insert to its regular edition, citing RAT as "a Product of All Station Teamwork," in which "UOD Plays Lead Role."[56] Several paragraphs were devoted to each of the departments and divisions involved in the effort, with a number of individuals cited for particular contributions. (See, for example, the personnel vignette on

[54] *Magnificent Mavericks*, 347–349.
[55] NOTS *Rocketeer*, February 14, 1958.
[56] NOTS *Rocketeer*, March 14, 1958, B-1 to B-4.

Harry Humason at the end of this chapter.) The first page of the insert singled out Doug Wilcox, who oversaw the project, citing him for his "firm belief in the effectiveness of a government laboratory staffed with outstanding scientists and engineers and working in close cooperation with Fleet officers assigned to provide insight on the Navy's needs," and Wally Hicks. Hicks led the systems analysis, which allowed the project to meet tight deadlines.

Interestingly, the article also made the bold claim, "RAT may become even more famous for its role in bringing effective systems engineering to the underwater field than for its ASW implications." The end of that statement was particularly telling, since the Bureau of Ordnance initiated a series of repetitive requirements for greater range that led to equally repetitive design changes and precluded any lasting ASW capability for the fleet. In fact, the weapon's failure against fast-moving targets led to program cancellation by the end of 1958.[57]

ASROC

As station engineers were still responding to new BuOrd requirements for RAT, the bureau was looking ahead to a much larger concept, replacing it with a device more along the lines of a Weapon A, one armed with a nuclear depth charge. In the early planning stages, NOTS was seen as having a much lesser role than it had shouldered for RAT.

The station's technical director, Bill McLean, sat in on one of the planning meetings and spoke out against the finality of a nuclear weapon. He suggested a more flexible approach, developing a rocket-propelled weapon that could carry either the nuclear depth charge in favor, or a lightweight torpedo. He offered the services of NOTS to develop such a weapon. By that time, the planning committee was formalizing the name NOTS had used as more of a descriptor on a number of earlier weapons—Anti-Submarine Rocket (ASROC).[58] They agreed with McLean's suggested alternate approach, but assigned it to another Navy lab.

Attending a meeting at which that laboratory presented its proposed development plan, NOTS department head Barney Smith reported it his associates in the desert. Both he and those associates disagreed with the proposed approach,

[57] *Magnificent Mavericks*, 351.
[58] *Magnificent Mavericks*, 349.

and immediately a trio of NOTS engineers including Don Moore spent a long weekend building a prototype demonstrating a different, more practical design:

> So we designed that on Friday night and Saturday and built it in the shop on Saturday and Sunday and fired it on Monday morning. We developed the film Monday afternoon before Barney [Smith] got on the airplane and took the red-eye [overnight flight] back and showed everybody that 'You guys ought to give us a shot. We know how to do things.'[59]

Based on that heroic effort—confirmation of the oft-repeated McLean philosophy weapons designers required a machine shop and test range on-site—and Smith's salesmanship, the Bureau of Ordnance gave the project to NOTS. (It was classic McLean: "Don't show words and try to explain what you're thinking about building; go build one, fire it on the test range, film the test, and take the film to show in Washington.") Undoubtedly to the chagrin of the threesome that had devoted an entire weekend to prove the value of their organization, and especially to Barney Smith who had emulated the style of his boss so expertly, the Bureau of Ordnance assigned the ASROC development lead to NOTS Pasadena.

Doug Wilcox was tasked with reprising his earlier leadership role on RAT. His initial report to the NOTS Research Board in May 1956, offering two different approaches to the weapon airframe, greatly impressed the board and McLean, who would select him to head the Underwater Ordnance Department a month later.

Joint China Lake-Pasadena effort

Work began immediately on the new weapon system, with China Lake concentrating on the rocket motor and Pasadena working on the systems to launch and guide the weapon:

> Since the ASROC program ultimately involved most of the technical departments at China Lake as well as at Pasadena, Wilcox spent at least a day a week on the desert working to keep communication lines open. Pasadena was responsible for work on the nuclear depth bomb and the airframe, plus the integration of all the systems; the Rocket Development Department took on responsibility for the rocket motor; and AOD [Aviation Ordnance Department] built the electronic separating device and integrating accelerometers. Much of the testing was done at China Lake, where the isolation of the desert helped ensure secrecy.[60]

---

59 Don Moore interview, 22.
60 *Magnificent Mavericks*, 451.

Recognizing his exceptional management abilities overshadowed his engineering skill set, Wilcox reached down into the Pasadena workforce for promising mid-level-management engineers, selecting Charles G. “Chuck” Beatty to take over the Torpedo Development Division, and DeVirl A. “Bud” Kunz to handle his former job heading RAT development. Jim Jennison, who had already made his name with the VAL at Morris Dam and the SNORT track at China Lake, headed the engineering function. The trio, working closely under Wilcox’s direction, would serve as the Pasadena leadership team for the next two decades and would migrate the show intact to San Diego when Pasadena closed in 1974.

Barney Smith, who had played a substantive role in bringing the project to NOTS and then been devastated when leadership was placed elsewhere (although, thankfully, still within NOTS), put aside his disappointment and plunged into the effort, managing rocket motor and depth charge fuze development. Personnel in the Aviation Ordnance Department, under a pressing, six-month deadline, developed the Range and Airframe Separation Programmer (RASP), a magnetic core device that served as the ASROC control unit. Just before weapon launch, shipboard equipment transmitted critical missile data to RASP, which then accelerated the missile to proper speed and detonated an exploder to separate the motor from the airframe. When separation time arrived, RASP detonated another explosive device to separate the airframe from the payload (a lightweight acoustic homing torpedo or a nuclear depth charge). The payload dropped into the water.

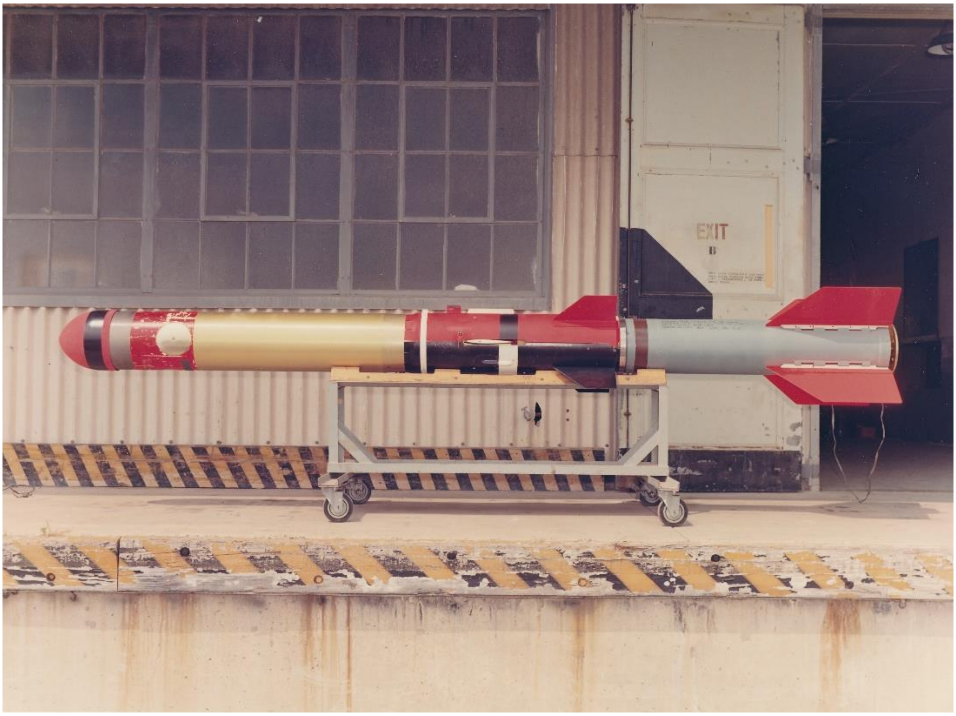
In the case of a torpedo payload, there was a concern similar to that of the RAT payload, that high-speed water impact would damage the weapon. Mort Heinrich, technical expert for ASROC torpedo payload Mark 44, explained the Variable Angle Launcher at Morris Dam was employed to test the Styrofoam-filled plastic nose cap designed to protect the torpedo. Substantial research went into shaping the Styrofoam so it would break away cleanly upon water impact. VAL tests confirmed the success of that research, since unpowered torpedoes merely sank and the Styrofoam floated to the surface. When actual sea runs were made, however, with the torpedo engine propelling it, pieces of Styrofoam adhered to the torpedo’s nose, causing cavitation. Redesign of the nose caps solved that fairly complex and unforeseen problem.[61]

ASROC’s Mark 111 Fire Control Group was the first digital controller for a major weapons system. The Mark 111 was a programming wonder of the time, integrating data from sonar, weather indicators, range and position sensors,

[61] Mort Heinrich SSC Pacific interview, 25-26.

compasses, launch systems, and more, to direct an accurate arming of the missile guidance and launch systems.[62] The propulsion system employed several innovations, including a variable thrust controller allowing the missile to adjust its flight path. An eight-cell shipboard launcher was developed for the missiles.

The scope and complexity of the ASROC system was such that every NOTS department, and "virtually every major technical element on the Station," played



NOTS-developed Anti-Submarine Rocket with Mark 46 torpedo payload.

a large or a small role—airframe design, missile trajectory, shipboard launcher development, production engineering (seeking the most cost-effective approach for contractor production), simulation runs (more than 6,000 were made).[63] The vast, intricate testing required was conducted at every geographical location the station managed—China Lake, Morris Dam, Long Beach, San Clemente Island.

---

[62] "Capability Improvement Program for Fire Control Group Mk 111 and Fire Control System Mk 114," brochure, Librascope Division of the Singer Company, undated.
[63] NOTS *Rocketeer*, July 8, 1960, B-2.

Some concept of that complexity can be gained from reading through the four-page insert to the *Rocketeer*'s July 8, 1960 issue, detailing the work of scores of engineers, scientists, and staff personnel who managed literally hundreds of other station employees involved, not to mention a number of BuOrd naval officers and hundreds of contractors. In the principal article about the leadership team, Doug Wilcox was singled out appropriately for special recognition.

The probable stimulus for that special issue occurred a month earlier, in June 1960, when four unarmed ASROC-boosted torpedoes were launched successfully against the submerged nuclear submarine USS *Skate* (SSN-578) at ranges from 2,000 to 6,000 yards.[64] Early in 1961, ASROC achieved initial operational capability, followed by installation on a large number of surface ships as their principal anti-submarine weapon.

The station newspaper of January 13, 1961, noted:

> A new and powerful anti-submarine weapon known as ASROC joined the fleet. The front half of the missile is a torpedo and the rear a solid propellant rocket. When fired, the rocket booster falls off and a parachute lowers the torpedo into the water. Guided by an acoustical homing device, it closes on its target at high speed.[65]

Several months later, a demonstration of ASROC was conducted for the news media in Key West, Florida.[66] And on May 11, 1962, the Navy demonstrated ASROC's standoff capability in a dramatic test in the Pacific Ocean 370 miles southwest of San Diego. USS *Agerholm* (DD-826) launched an ASROC with a nuclear depth charge, the explosion of which sent a vast hemisphere of radioactive seawater 750 feet in the air.[67]

ASROC was deployed to destroyers, frigates, and cruisers through the 1960s, and like the Sidewinder and Mark 46 torpedo, it proved long-lived and adaptable. Improvements were made in the launch control system, most notably in the upgrade to the Mark 114 Fire Control System, and later, the Mark 116 system that NOTS Pasadena programmed. The Mark 116 integrated systems of computing and display with the flexibility to handle different forms of combat from standoff attack to search-and-destroy missions.

---

[64] NOTS *Rocketeer*, June 24, 1960, 1.
[65] "Navy Records Many Firsts," *Rocketeer*, January 13, 1961, 4.
[66] NOTS *Rocketeer*, May 19, 1961, 1.
[67] U.S. Navy film "ASROC Nuclear Weapons Effects Test," https://www.youtube.com/watch?v=EV5q_mlhaiM, accessed March 30, 2015.

Eventually, when the Navy determined to adopt vertical launch systems for its surface ships, Point Loma laboratory weapon developers would re-design ASROC in that mode, as we shall see in Volume II.

If one system can be said to have merged NOTS's two great domains of weapons expertise—rockets and torpedoes—it is ASROC, which, in an upgraded instantiation, was still operating in the fleet more than half a century later.

Special Projects Office

The weapons race between the U.S. and the USSR turned in the early 1950s toward ballistic missiles, weapons power-launched from the surface in a high, arching trajectory that after reaching apogee descended under the influence of gravity to the target. Substantial in-fighting for leadership on the emerging weapon technology occurred between two principals in the Navy's bureau structure, with the Bureau of Ordnance claiming ownership based on its history of developing underwater and sea-launched missiles, and the Bureau of Aeronautics countering with its experience with Regulus, the Navy's first operational cruise missile.

To deal with that contentious issue and another problem related to ship launching of a proposed joint Army-Navy program involving the Jupiter missile, the Secretary of the Navy in 1955 established the Special Projects Office. SPO was a small office separate from the bureau structure, which had been the driving force behind all Navy technology acquisition for more than a century (see Chapter 1). In addition to Rear Admiral William F. Raborn, Jr., who headed the office, two of the early top managers had ties to NOTS: Captain William A. Hasler had been the second Pasadena Annex officer-in-charge (1948-1952), and Captain Levering Smith, chosen to manage the SPO Propulsion Branch, had been a China Lake department head and the NOTS associate technical director, an assignment never previously held by a non-civilian.

Within a few weeks of his arrival, Smith reached back to NOTS, asking for a study on the possibility of a successful submarine-missile "marriage," with the striking consideration the proposed Jupiter-S missile was monstrous—43 feet long, 10.5 feet in diameter, and weighing in at 80-plus tons! SPO planning called for test missile launch in two years (1958), submarine testing in five more, and deployment of the missiles on submarines two years later (1965). Not surprisingly, the China Lake response was negative. The negative came with a positive, however: there was a reasonable opportunity to develop a 30,000-pound missile powered by solid propellant, and it could be deployed much sooner than 1965.

As related in substantial detail in the next chapter, NOTS personnel played an overwhelming role in convincing top Navy officials a much smaller weapon could be designed, developed, tested, and fielded in substantially less time than early estimates, with the capability to "essentially wipe out Soviet government control."[68] China Lake studies on the subject included the concept, essentially adopted later as U.S. military policy, of deterrence rather than retaliation.

Not only did NOTS personnel provide philosophical planning, but they helped design the missile and develop the needed underwater testing facilities. By June 1958, an inert Polaris missile was launched at San Clemente Island for press personnel, and in 1960 the first live firing at the island April 14 was followed by submarine launch of the actual first operational missile July 20.

The Polaris story, and the substantial participation of the NOTS China Lake and Pasadena facilities and personnel, will be told in detail in Chapter 8.

Pasadena area facilities

The rationale for moving some principal operations of the California Institute of Technology rocket program to the Mojave Desert was its hundreds of square miles populated by sparse vegetation and even sparser habitations, which allowed long-distance firing of explosive weapons without killing someone or setting something on fire. However, in addition to the obvious major resource of the Caltech laboratories, there were clear reasons for not moving everything. Maintaining a substantial presence in Pasadena, with its proximate sources of contract personnel, suppliers, and manufacturing capabilities, was deemed an appropriate measure to support the desert testing.

The establishment of the Naval Ordnance Test Station in the middle of the war provided the beginnings of a permanent Navy presence in the desert, with a headquarters as well as improved test facilities. After the war, facilities in the city also became more permanent Navy organizational elements. The Morris Dam

---

[68] *Magnificent Mavericks*, 334.

facility, site of Mark 13 torpedo testing by Caltech personnel, was the first to become part of the NOTS real estate in the Los Angeles area. Identified as a formally recognized organization element, it thus warranted its own officer-in-charge, Commander W.H. Keighley, who was appointed shortly (almost precipitately) after the end of the war. Identified as the "Morris Dam project," it later included NOTS Pasadena.[69]

For several years after war's end, the physical plant on Foothill Boulevard was a contract facility, transferred to NOTS by the Bureau of Ordnance but managed temporarily by General Tire and Rubber. Commander H.D. Hilton arrived as first officer-in-charge sometime in 1946. One of his responsibilities was preparing the contract employees to transition into civil service, 430 of whom did so on July 1, 1948. Shortly thereafter, he was relieved by Commander William A. Hasler, who had been his deputy, and moved to his next assignment.

Over the next several years, the reorganization of the Physics and Research departments allowed the command to vacate the buildings it had occupied on Green Street during the war. The Thompson Lab, established in a former grand hotel for a brief period after the war, was shuttered as well. That left the major Pasadena area holdings of the test range at Morris Dam and the manufacturing facility and emerging weapon development plant on Foothill Boulevard.

What it didn't leave was an appropriate place to test new-development torpedoes. As Caltech's Charles Lauritsen had been forced to journey into the Mojave Desert to find a place to launch long-distance highly explosive rockets, so the China Lake-based Research Board and Pasadena Annex personnel needed to find a suitable location to test deep-diving, long-running torpedoes. Morris Dam, although it was used for air-drop testing of torpedoes, lacked the volume (surface area and depth) required for the appropriate testing of the weapons to be developed in Pasadena. Several lakes near China Lake were considered, but there were challenging issues associated with them, such as potable water contamination. Employees at the Foothill facility suggested an alternative: San Clemente Island.

San Clemente Island provides testing venue

San Clemente, the southernmost of California's Channel Islands, had been under the Navy's control since Franklin Roosevelt transferred responsibility from

---

[69] NOTS *Rocketeer*, November 8, 1955 and November 8, 1958.

the Department of Commerce to the Secretary of the Navy "for naval purposes" in November 1934. Over the next several years, civilian crews constructed a barracks, a mess hall, headquarters and operations buildings, and a fire station.[70]

Although the island was used only sporadically before World War II, it could claim reasonably that the 1937 training exercise featuring amphibious landing by

San Clemente Island would provide NOTS and its successors the perfect venue for testing of weapons and undersea vehicles and equipment.

---

[70] Wilfred J. Sturgeon, *San Clemente Island: A Chronological Military History (1932-2000)*, 2002, 4.

4,700 Army and Marine personnel to "capture" the island was one of the two essential stimuli for the establishment of the U.S. Navy's amphibious forces. During the war, the island, fairly close to San Diego and Long Beach, but "remote" in terms of accessibility by the general public, served as an ideal location for shorebombardment by fleet surface ships, landing and maneuvers by troops, aerial bombing practice, and safe training in the use of machine guns and small arms. Existing in a caretaker status with a handful of maintenance personnel after the war, it provided a promising environment for torpedo testing, and ultimately for four decades of experimentation on ballistic missiles, underwater vehicles, surveillance arrays, and shipboard sonar and radar calibration.

In 1951, NOTS negotiated with the Eleventh Naval District for use of the island and began installing underwater test fixtures, piers, roads, and launch and documentation camera sites along the steep escarpment on the eastern side of the island. Since the island had very few natural resources, several contracts were established over the years for barge service to bring food, vehicles, equipment, essentially everything required, including water.[71] (In fact, in the "small world" category, in 1962 the desalinization plant on Point Loma, operating on the site that would later become the Center's Marine Life Sciences Lab, was placed on a barge for transfer to SCI to meet the island's need for fresh water. The Cuban missile crisis and resulting cut-off of water supplies to the U.S. naval base there resulted in the re-routing of the desalinization plant to Guantanamo Bay. More than half a century later, fresh water is still barged weekly to the island.)

The requirement for barge service necessitated a mainland terminus for staging equipment and supplies slated for transport to the island. A logical location was Long Beach, site of one of the major West Coast shipping ports and as well of an important naval station and Navy shipyard. NOTS Pasadena established a presence there of Navy officers and enlisted personnel. They operated a fleet of small craft, such as torpedo recovery boats, to support weapon and other underwater testing at San Clemente Island and as well on the Long Beach Sea Range, a large area of the Pacific near the naval station set aside for Navy exercise and testing purposes.

To augment the permanent facilities at the island and Long Beach, Pasadena Annex employees of the Underwater Ordnance Department (UOD) built the Deep-Depth Launching and Test Facility, a five-hundred-ton motorized barge

[71] Sturgeon, *San Clemente Island*, 23.

floating on pontoons left over from construction of the Variable Angle Launcher at Morris Dam. Christened *Trygon* and launched in October 1951, the ungainly but effective vehicle included a well in its middle that could lower a platform down to six hundred feet, loaded with instruments to measure noise and vibration. When operating off the coast at the Long Beach Sea Range, its mobile measuring capabilities were an improvement over the fixed facilities located at Morris Dam.[72]

UOD laboratory personnel also employed the barge to study the peculiar effects of sea life, temperature, and currents on the propagation of sound waves in salt water, as one of many basic research studies aimed at improving the operation of the torpedoes under development.

In the summer of 1961, administrative command of San Clemente Island was assigned to NOTS. By then, the island had living quarters for two hundred, as well as shops, fire control buildings, and a number of instrumentation stations.

Welcome site name change

Speaking of facilities: the reader with an exceptional memory might recall in the first chapter a brief description of the arrival in the desert in early 1944 of Captain Oscar A. Sandquist, first permanent Officer-in-Charge-of-Construction of the test station. One of his early observations was building materials for the Quonset hut to serve as the first NOTS headquarters had been delivered to Inyokern, where the air field was located, whereas the site for administrative and laboratory facilities was ten miles away, at China Lake. He proposed moving the HQ materials to that location, where the commanding officer could begin commanding immediately at the scene of the action. A phone call to the Bureau of Ordnance gained necessary approval and Captain Sandquist handled the details.

What wasn't changed was the fact the Secretary of the Navy establishing order stated clearly it was sited at Inyokern, which presented some technical and administrative difficulties over the years. Those were handled effectively when a successor SecNav signed a notice dated 4 February 1955, officially changing the name/location to U.S. Naval Ordnance Test Station, China Lake, California.[73]

[72] *Magnificent Mavericks*, 341–342.
[73] One of the inherent difficulties of publishing a many-decades history of a Navy

Main gate of NOTS, finally and officially located at China Lake.

Training programs

In its June 26, 1959 issue, the NOTS *Rocketeer* announced: "91 New Jr. Professionals Arrive from 54 Colleges," further stating that 16 of them would be assigned to the Pasadena Annex. The following summer, another *Rocketeer* advised, "New Junior Professionals Report Aboard," listing 123 graduates arriving at China Lake. An article several issues later reported an additional 38 Junior Professionals were on board in Pasadena.[74]

---

laboratory, where name changes are all too common, is maintaining identity while attempting fidelity to the evolving organizational titles. With the benefit of hindsight, the excellent history of the organization in the Mojave Desert, with the first volume published in 1971 and the fourth in 2017, was called from the outset *History of the Naval Weapons Center at China Lake, California*. With the third volume, *Magnificent Mavericks*, that was shortened to *History of the Navy at China Lake, California*.

[74] NOTS *Rocketeers* July 15 and August 19, 1960.

These three issues enumerated 252 young scientists and engineers who had arrived in the summers of 1959 and 1960 at China Lake and Pasadena as part of the NOTS Professional Development Program.

Given the nature of the technical programs managed by NOTS, it was clear bright, highly educated personnel would be required to make the station successful. As a reasonable result, a process was initiated for recruiting scientists and engineers with the highest grades from the best colleges and universities. It was understood, however, that the academic environment could provide only the basics required for a fully qualified individual to work on Navy technical development programs.

With that in mind, NOTS Pasadena initiated the Junior Professional Assistant Program in 1948, a noteworthy early example of an institution formally training its personnel for the specifics of their employment.[75] Understanding the "salary restrictions, rigid job classification standards, and cumbersome hiring and firing procedures" involved in federal employment,[76] exacerbated by the challenges of its environment, NOTS headquarters in the desert soon adopted the program as well. Over the decades that initiative would play a key role in recruitment of thousands of young engineers and scientists who would become the lifeblood of the organization: "The thing that caused me to go to China Lake, which was by far the lowest-paying offer I had, was the fact that in the JP program, they would allow you to try different things and go to work in an area that attracted you."[77]

In its early days, the program was organized into two phases, the first of which involved three sixty-day assignments in different technical divisions.[78] The trainees spent each of those assignments working on a specific project, usually under the direction of a senior engineer, learning on the job the principles of Navy research, development, and engineering. One day a week they attended technical and management lectures, learned the art of report writing, and took field trips (which included trips to Pasadena for the China Lake JPs, and vice versa). The trips also included tours of the Navy surface ships and submarines on which the products of their engineering would someday operate, to better understand the rigors of the harsh and unforgiving environments in which those products had to function. And,

---

[75] Research Board minutes, 17 May 1948, 2-3, discussed in *Magnificent Mavericks*, 561, Footnote 38.
[76] *Magnificent Mavericks*, 128.
[77] Don Moore interview, 1.
[78] NOTS *Rocketeer*, January 20, 1956.

perhaps most important, they met the people—the naval officers and sailors—who would depend on them to provide technology that allowed those in uniform to execute their missions and after doing so return safely to port.

In the second phase, each participant was assigned to a division for six months of on-the-job training, generally on a specific project. After that, the JP would be assigned to a final position based on his or her interests and organizational needs .

Over the decades, there were minor modifications (e.g., shorter or longer tours, fewer or more of them), but the general principles of varied tours followed by a final assignment in which the JP had some reasonable voice remained the same. (One interesting result of that "reasonable voice" was the exception some participants took in the 1970s to the term "Junior." As a result, the terminology was modified to "New Professional," and JPs became NPs.) Another major selling point for most of the program participants was the offer, almost expectation, they would be afforded paid work hours to attend advanced college courses.

Over time, other significant program advantages became evident, according to Lee Zimmerman, an NP who eventually would become a department head and deputy executive director: "… the other thing that was nice, because we were bringing in people from all over the country: There was a little bit of a support net for folks who… maybe this literally was the first time they'd gone away from home and they were already on the far West Coast."[79]

Zimmerman's wife Laura Gilbreath was in the NP class of 1982, a year before him; she was one of the year-ahead "support net" group. Employed at the Center "in the large part because of the New Professional program," she agreed that

> a built-in peer group was a very, very nice thing. Like Lee said, a lot of people came in from out of town, didn't have family or friends here. But that gave you a social group of people that were kind of in your same situation, [who] were able to guide the newcomers a little bit in telling them… giving them suggestions—places to live, or places to go hang out, or whatever.[80]

---

[79] Lee Zimmerman, Gilbreath Zimmerman family oral history conducted by Tom LaPuzza, October 9, 2018.

[80] Laura Gilbreath, family oral history. Gilbreath herself lived in San Diego her whole life, arriving at the Point Loma lab after graduating from the University of California San Diego, ten miles away, with a computer science degree. Her father, Jim Gilbreath, appeared in Chapter 6. Six members of the Gilbreath-Zimmerman combined family contributed 150 years of service to the Point Loma lab, including Gary, son of Jim and Laura's brother, also a UCSD graduate, who programmed robotics projects for decades.

And in their specific case, one "whatever" the NP program provided was "a dating service as well," as Lee's NP "mentor" Laura eventually became his wife.

The NP program continues (in 2020) as the Point Loma laboratory's primary mechanism for hiring technical personnel. Not only does it provide job skills and career opportunities for young scientists and engineers just starting out to replace veterans retiring in a decade or so, but it offers benefits to the Center as well: fresh ideas, new outlooks, the latest technology advances, different approaches.

Training was not restricted to the college graduates: "Opportunity Unlimited for All Personnel" screamed a 72-point headline in the *Rocketeer* issue of April 10, 1959.

The full-page article related that training at NOTS began with an apprentice program in 1948, when major construction was underway at the station and skilled workers in the construction trades were in demand. Over succeeding decades, the need for skill sets to support highly technical programs resulted in training of hundreds for careers as mechanical engineering and electronics technicians, sheet metal workers, and machinists. Those who completed the training received associate of arts degrees from a local community college. Apprentice trainees who stayed on the job could take advantage of journeyman training to advance in their chosen fields.

The New Technician Program was similar to the JP program. It sought highly motivated junior college graduates to augment those trained on the job in the apprentice program. The forward-looking plan, typical of the test station, was to bring in younger technicians for mentoring before their aging peers left government service. Augie Troncale, completing his studies at Mt. San Antonio College in Los Angeles County, the largest community college in the U.S., was recruited in 1968.

He related his recruiting experience:

> Carl Runge, who was a senior tech at the Center in Pasadena, was my recruiter. Carl began the interview by detailing the Center's very successful [Junior] Professional Program. He then stated that the Center's current technicians were World War II era and they wanted to get some younger people into the pipeline to be trained as these folks may begin to retire.

As lab engineers were sent to universities to seek potential Junior Professionals, senior technicians visited local community and junior colleges to identify and recruit motivated candidates with applicable training in mechanical design and similar fields.

Troncale explained, "It was set up exactly the same [as the Junior Professional Program]. It was a great introduction to what ended up being my career for 25 years in torpedoes. I'm a hands-on, backyard mechanic kind of guy so this type of work fit perfectly with me."[81]

Need for highly qualified staff support personnel stimulated a Junior Management Assistants' program in 1949; it evolved over several years into the Junior Government Assistants' Program in 1954.[82]

The station sponsored a Supervisor Development Program as well, and, in the period 1956-1959, more than a hundred UCLA extension courses were offered to NOTS employees on station at China Lake, attended by more than 1,500 students.

The other principal laboratory involved in this history, at the time called the U.S. Navy Electronics Laboratory, experienced the same challenges of recruiting within Civil Service guidelines, and then augmenting academic excellence with the necessary training in the particular qualifications of a Navy lab technologist. Rather than its own program, NEL participated in the Navy Science Engineering Co-Op Program administered by the Navy's Bureau of Ships, its principal sponsor. Under that program, high-achieving students were recruited out of high school for a five-year period that included thirty-six months of college classes and about twenty-four months working at the Navy lab. Program participants accepting financial aid to defray college expenses were required to work one month at the lab for each month of paid university attendance. The NEL program began in 1957, and three years later forty-one student-workers were involved.[83]

---

[81] Troncale was also a perfect fit for the technician program, dispatched so immediately to the Morris Dam facility he had to take off the coat and tie he wore to his interview to begin work. Shortly after, the Navy called him up to active duty. Declining the offer of a job-related deferment, he served as an aircraft carrier sailor off Vietnam for seventeen months before returning to the lab for a government career of more than thirty-five years. (Augie Troncale SSC Pacific oral history interview conducted by Tom LaPuzza, July 12, 2012).

[82] See *Rocketeers* of October 5, 1956 and May 3, 1957 for stories on participants in the Junior Government Assistants' Program.

[83] "Co-Op Program Encourages Students in Scientific Fields; Work, Studies Aid in Future Careers," NEL *Calendar*, 5 August 1960, 2.

Contributing organizations

As has been mentioned several times, important organizational elements of today's Naval Information Warfare Center (NIWC) Pacific originated in other organizations in other places. The late twentieth-century phenomenon of military base closures and mergers was predicated principally upon three significant factors: one, there wasn't enough money to fund the vast infrastructure the military developed over the decades; and two, although complete closure of some facilities was reasonable, the military often recognized a small (or large) component of a base was critical to its needs and therefore should be exempt from closure. The result, which in a significant number of instances favored NIWC Pacific, was a merger of one or several components of a base, the rest of which would be shuttered. (The third factor, by the way, was politics, which will not be addressed.)

Take, for instance, Warminster, Pennsylvania, north of Philadelphia. The Brewster Aircraft Company had manufactured dive-bombers for the Navy in Warminster during World War II. The Navy took over the facility in 1944, and in 1953 the Naval Air Development Center (NADC) absorbed the aircraft navigation function from the Philadelphia Naval Shipyard. NADC was responsible for design and construction of guidance systems for target drones, special aircraft, and guided missile systems.

Warminster's work was similar to the pursuits of NOTS Pasadena and NEL. For example, its Aeronautical Electronic and Electrical Laboratory's mission was to provide Navy aircraft with the latest in radar and other electronic gear, and the Aircraft Armament Laboratory worked on bomb and rocket release mechanisms. In 1950, RCA built the largest electronic analog computer in the world for NADC's Analytical and Computer Laboratory. Its purpose was to analyze weapons components early in the design process.[84] In addition, anti-submarine warfare technologies such as sonobuoy arrays were an ongoing object of study.[85]

In 1964, NADC built a laboratory called the Inertial Navigation Facility. It provided a unique work environment, designed with twelve piers bonded forty feet down to bedrock to render noise and vibration virtually nonexistent. Here engineers built and tested electronic inertial guidance systems of gyroscopes,

[84] "Research to Reality," *Naval Aviation News*, November 1955, author unknown.
[85] Roger A. Holler, "The Evolution of the Sonobuoy from World War II to the Cold War," *U.S. Navy Journal of Underwater Acoustics*, January 2014, 322–342.

accelerometers, and computers enabling pilots, ship navigators, and missiles to track their position.[86]

Through generations of engineering, this became the basis of marine navigation inertial systems on submarines and the missiles they carry. Work beginning in the 1970s also assigned the laboratory staff responsibility for development of the military Global Positioning System. The Base Closure and Realignment Commission action of 1991 resulted in transfer of an entire NADC department, including all its navigation projects, to the Point Loma Navy lab.

Ensign Robert M. Hillyer reports aboard

At the Naval Ordnance Laboratory in Corona, California, 40 miles southeast of Los Angeles, a young naval officer reported aboard in 1957. It was the first duty station for Ensign Robert M. Hillyer, who had been educated at the University of Idaho on an NROTC scholarship. His comment decades later was to the effect he was sent to Corona because the Navy feared he might sink one of its ships if sent to sea. His civilian supervisor put him to work on safety-arming devices and contact fuzes for Sidewinder missiles. It was a somewhat inauspicious beginning, except that Bob Hillyer found working at a Navy laboratory was really a lot of fun. As we will discuss in Volume II, it was as good for the Navy as it was for him.

Beatrice and Harry Humason

The NOTS Pasadena Annex was fortunate to employ a mother-son physicist-engineer duo in Bea and Harry Humason, one of a number of parent-child employee relationships throughout the history of the organization. (The August 12, 1960 issue of *Rocketeer*, in its Pasadena Annex section, advised among the 750 employees at the time there were at least twenty-six "relational" pairs—

[86] Joseph Dunphy, "Johnsville Center Leads Nationwide Naval Research," Philadelphia *Inquirer*, November 23, 1969.

sixteen sets of husband-wife employees, three sets of parent-child, two of siblings, and one of a grandmother and granddaughter.)

Bea Humason, a 1919 Stanford physics-mathematics graduate with minors in astronomy and chemistry, taught practical astronomy to Stanford engineering students. As assistant to George Hale at Mount Wilson Observatory from 1920 to 1928, she performed astronomical computations and published a number of papers on variable stars, star clusters, and sun spots.[87]

Bea's involvement with the organization began in 1944, shortly after Caltech initiated efforts to improve Mark 13 torpedo performance. She provided data assessment services on that project and several others during the war. Afterward, she elected to stay on and join civil service with the fledgling NOTS organization. Except for three years as a project engineer in another department, she spent her NOTS career performing analysis of film, oscillograph runs, and sound tapes for torpedo testing in the Underwater Ordnance Department.[88] The exacting analysis work was often tedious, but "worthwhile… when you look toward the results obtained in learning missile behavior and total effect of run results," she told an interviewer. After working on a wide variety of UOD projects, she retired in August 1966, with twenty-one years federal service. Retirement allowed her additional time for her substantial outside activities, which included the American Association of University Women and Rose Bowl Riders.

After graduating from the same high school his mother attended, Harry Humason joined the Army's Fifth Infantry Division, serving in Germany. After his discharge from WWII service, he attended the University of California at Berkeley (where his mother had spent her first college year), graduating with a mechanical engineering degree in 1951. Joining the Pasadena Annex staff as a Junior Professional, he completed his JP tours and was assigned to the Design and Production Department. In 1954 he transferred to the Underwater Ordnance Department, where his mother worked in the Analysis Branch. As head of the engineering section in production engineering, he worked on the Rocket Assisted Torpedo and the Mark 43 Mod 1 torpedo. His focus was to prepare prototypes developed in the RDT&E process for actual production in large quantities by contractors, ensuring high quality products that were also cost effective.

---

[87] NOTS *Rocketeer*, March 30, 1956, 3.
[88] *Rocketeer*, June 10, 1960, 3.

A 1958 issue of *Rocketeer* reported,

> Engineering for production has paid off in RAT. Harry Humason and other engineers and production specialists working with him produced… practical improvements [that] made RAT relatively easy to produce. The most striking improvement was in the airframe where cost was reduced by 50 per cent. The fins are an example. Replacing the internal aluminum framework with plastic foam poured into the fin shell reduced cost 64 per cent and eliminated 164 blind rivets… Later the cost was cut in half by substituting a Styrofoam wedge cemented into the fin for the poured plastic. The final result of product engineering was an airframe which had good producibility and weighed 25 per cent less than the early development models.[89]

Also involved, Bea conducted data reduction and film analysis of RAT testing.

Harry spent much of his later career in the Engineering Department's Mechanical Engineering Branch, heading it for several of those years. With the closure of the Pasadena Lab in 1974, he transferred to San Diego, rounding out his career working in structural mechanics at the Bayside complex. He was presented his thirty-five-year service award in early 1983, and retired shortly afterward.

Bea and Harry Humason

[89] *Rocketeer*, March 14, 1958, B-2. Also: Harry Humason, "Producibility Features of the RAT Airframe," *Torpedo Quarterly*, November 1954, 7-14.

8

Headline Year: 1960

Sometimes a whole series of events coalesces into a perfect storm of human endeavor or creativity in a short and specific timeframe, say maybe a year: Newton's was the year 1666, when he "developed calculus, an analysis of the light spectrum, and the laws of gravity." Albert Einstein's occurred in 1905, when he wrote papers on light quanta, molecule size, Brownian motion, and his famous theory of relativity.[1]

The infant year of the 1960s, viewed by many as a particularly notable decade, was in itself indicative of things to come, with a number of newsworthy events: The non-military, musical British invasion launched by the Beatles began, surprisingly in Germany. In the U.S., where that invasion would spread relatively quickly, much of the current focus was on civil rights, beginning in February with a student sit-in at a Woolworth's store in Greensboro, North Carolina; continuing with passage by the Senate of a landmark civil rights bill in April; and followed by the set-back of the arrest of the young minister who would be monumental in the effort during another sit-in in Atlanta. In February, the Winter Olympics were held in Squaw Valley, California. The results of the decadal census, which were published on April 1, reported, no fooling, that there were 179,245,000 Americans. A goodly number of them lived on the distant Pacific islands of Hawaii, whose star joined the forty-nine others on the blue field of the American flag on the Fourth of July.

Just a week before the census announcement, Arthur Schawlow and Charles Townes were granted the first patent on a laser.[2]

On November 8, a handsome, charismatic young man with a beautiful wife and two small children replaced decades of elder statesmen as prospective residents of the White House, which had not seen First Children since the early 1900s. Quentin Roosevelt was nearly four years old when his father Theodore was

---

[1] Walter Isaacson, "Chapter 5: The Miracle Year: Quanta and Molecules, 1905," *Einstein: His Life and Universe* (New York: Simon & Schuster, 2007), 93.
[2] *Today in Engineering History*, March 22, 1960.

inaugurated in 1901, as was Carolyn Kennedy when she took up residence in January 1961 with her parents John and Jackie and her baby brother John, Jr.

For the United States Navy, 1960 featured significant events as well, beginning about 36 hours before the year rolled over. On December 30, 1959, the Navy launched its first ballistic missile submarine, USS *George Washington* (SSBN-598). On the following July 20, the sub would be the first to launch a Polaris missile (more about that shortly), signaling operational capability of the third and most survivable leg of the nation's nuclear triad. The Navy's first nuclear aircraft carrier, USS *Enterprise* (CVN-65), was launched in September. A few months earlier, the nuclear submarine USS *Triton* (SSRN-586) had completed a submerged circumnavigation of the globe.

The year 1960 was memorable in the history of the San Diego Navy laboratory as well. At that time, the entity now concentrated in large real estate holdings on Point Loma with a few smaller Pacific locations consisted of two Navy R&D organizations, two headquarters complexes and another fairly large laboratory site, and five or six "facilities" in California, but also in other states.

The electronics laboratory on Point Loma would celebrate its twentieth anniversary June 1, 1960. Evidence suggests, however, lab management elected not to include the five years of the Navy Radio and Sound Laboratory as part of its history in those days.[3]

Less than a year before that, NEL had transformed its weekly mimeographed listing of meetings and important visitors into a real newspaper chronicling the people and projects that characterized the lab and its mission, which was:

> Conduct research, development, and tests in the field of electronics and the related fields of engineering and science, including radio, radar, sonar, oceanography, and the instrumentation for an analysis of environmental weapons effect and human factors; and provide consultative service and sea test facilities as authorized for the Fleet, for Navy contractors, and for other agencies of the Department of Defense.[4]

---

[3] Navy Electronics Laboratory *Calendar* of 2 December 1960, 1: "Formally established on 29 November 1945, the Navy Electronics Laboratory this week marks the completion of its fifteenth year of ever-growing expansion and progress." Also, in the same issue: "Fifteen year Service Pins were awarded Tuesday, 19 November, to a group of employees who have been continuously employed at NEL since 29 November 1945. This group of 129 eligible persons were previously employed by the Navy Radio and Sound Laboratory or were appointed directly from the University of California Division of War Research."

[4] *Calendar*, 2 December 1960, 3.

For the first time, articles about lab personnel also included photographs. The first such issue, March 25, 1960, published a front-page photo of engineering officer Lieutenant Commander M.D. Van Orden, plotting a position on an OMEGA navigation chart. He would return to the *Calendar* front page of June 24, 1969, when, as Captain Van Orden, he assumed command of NELC.

Several hundred miles northeast, the Naval Ordnance Test Station celebrated its seventeenth anniversary on the day Kennedy was elected. Half a year earlier, as had occurred for some years in the past and would continue for many more in the future, NOTS had observed Armed Forces Day with an open house. A spectacular air show and impressive displays of the weapons developed by the station greeted thousands of employees, their families and friends, and members of the Ridgecrest business community who depended heavily on the base for their survival.

NOTS had determined early on the importance of a newspaper, reporting not only on Navy lab personnel and programs, but also on the civilian community, including Burroughs High School, named for the first station commanding officer, Captain Sherman E. Burroughs. The paper, after several short-lived titles, took the appropriate name *Rocketeer* in the spring of 1945.

The spring 1960 Armed Forces Day celebration extended south to the station's major laboratory in Pasadena, which apparently had some control over its own coverage in the NOTS newspaper souvenir edition,[5] deleting the unpleasant appellation "Annex" from its title and citing itself throughout as "NOTS Pasadena." According to the special issue:

> The principal objective of NOTS Pasadena is to plan and conduct a program of research and development in the field of underwater ordnance, including complete torpedo and missile weapons systems for the Fleet. NOTS carries ordnance development through from inception of an idea to the production stage.

Major coverage was given to the Polaris missile, Variable Atmospheric Tank at Pasadena, and sling-shot launcher at Morris Dam. The next *Rocketee*r edition (May 27) reported five thousand visitors attended the Pasadena show, which for safety, security, and perhaps other reasons was held at the nearby Naval Reserve Training Center, on the edge of a city recreation area called Victory Park.[6]

---

[5] NOTS *Rocketeer*, May 21, 1960, A-3.

[6] The park is the end point of the Rose Parade, the 71st of which was held January 1, 1960, with Vice President Richard Nixon as the Grand Marshal. (Later in the year, he would be defeated by Kennedy in the presidential election.) While the normal parade spectator spent

Press Coverage

And speaking of press coverage:

Brisbane (Australia) *Courier-Mail*, January 25, 1960, Page 1: "Seven-mile plunge into the Pacific; SCIENTISTS SET RECORD." "Two United States Navy scientists descended in a bathyscaphe yesterday into the deepest hole in the sea, more than seven miles down in the chill and dark bottom of the Pacific Ocean off the island of Guam."

As it has done in other areas of technology, the Navy "bought" the hadal-depth capability provided by the bathyscaph *Trieste,* with little actual development of its own.[7] At the same time, man's quest for highest-fastest-deepest would not have resulted in bottoming out in the Challenger Deep without the U.S. Navy, or at least it certainly would not have occurred in early 1960 without the Navy. And the Navy wouldn't have been able to take the credit had it not been for a couple of its relatively minor personnel.[8]

But first things first.

Homo sapiens evolved over the millennia with a remarkable ability to prosper on the surface of the planet Earth, and short distances above and below it. However, take the average human being and place him or her a few thousand feet underwater or in the air, and the pressure (or lack thereof) of the medium threatens the very existence of that human. Recognizing this limitation, but interested in projecting man to great altitudes or comparably great ocean depths, scientists have

---

a festive but chilly night in a lawn chair on a Colorado Boulevard sidewalk or paid a substantial sum for a seat in the grandstands erected along the parade route, NOTS Pasadena personnel could get free tickets to viewing stands at the Naval Reserve Center, where the parade ended. There, parade participants split into one group

[7] Jacques Piccard and Robert S. Dietz, *Seven Miles Down* (New York: G.P. Putnam's Sons, 1961), 115. Bathyscaph inventors Auguste and Jacques Piccard hoped to lease Trieste to the U.S. Navy. The latter declined, wishing to own the craft outright.

[8] Following the Deep Dive, the principals were awarded by President Eisenhower, meeting as well with Chief of Naval Operations Admiral Arleigh Burke. "To say the least, he was delighted that we had actually done it. He also seemed especially relieved that a junior civil service oceanographer and two Navy lieutenants had actually carried off this 'first.'" Don Walsh, "In the Beginning…A Personal View," Marine Technology Society *Journal*, Volume 43, Number 5, Winter 2009, 12.

sought body coverings (pressure suits) or enclosures (pressure vessels) to enable a fragile human to go where he otherwise could not. One of those scientists was the Swiss physicist Auguste Piccard.

Piccard, interested in cosmic radiation and its potential to confirm some of the theoretical work of his acquaintance Albert Einstein, built a spherical aluminum gondola which he could pressurize and thus preclude the need for a pressure suit. In 1931, he and a fellow scientist employed the device to ascend an astounding 51,775 feet over Germany. With no propulsion capability, the pair wandered over Germany and Italy before finally landing on a glacier in Austria. Subsequent ascents (more than twenty-five) reached altitudes surpassing 75,000 feet.

After five years or so of pursuing ever-greater heights, Piccard's interest turned 180 degrees as he considered descending into the depths of the sea. It occurred to him his gondola for pressure resistance at great heights might be modified to reach similarly great ocean depths. With financial assistance from the Belgian National Fund for Scientific Research, *Fonds National de la Recherche Scientifique* (FNRS) (which had supported his balloon experimentation and so he named it for that organization), he built the first of several craft he called bathyscaphs, employing French terms for "deep boat."

Bathyscaph principles were fairly simple: A "float" similar to the balloon of the high-altitude flights was positioned above the "sphere," comparable to the flight gondola. The sphere, fashioned of thick steel, provided a one-atmosphere environment for people, protecting them from the deep ocean's crushing pressure. The float provided both positive and negative buoyancy, with aviation gasoline (lighter than water and insoluble in it) the positive force, and the substantial weight of the sphere most of the negative. Interestingly, the positively buoyant gasoline also made the craft about a hundred tons heavier on the surface, precluding a small support ship lifting it out of the water for transport. As a result, it had to be towed on the surface from a nearby port to the dive area.[9] Sixteen tons of BB-sized iron shot were stored in two hoppers in the float; two tanks could be filled with sea water to increase downward momentum. Venting of gasoline, flooding or venting of the water tanks, and dropping iron shot allowed the bathyscaph to descend to the depths, return to the surface, or hover at mid-depth (fairly difficult).

Piccard oversaw construction of the first deep ship, *FNRS-2*, and he and son

[9] Lieutenant Don Walsh, USN, "The Bathyscaph TRIESTE: Technological and Operational Aspects, 1958-1961," NEL Report 1096, 27 July 1962, 4.

Jacques made the first dives. Unable to finance both construction and operation, the Piccards turned the craft over to the French navy, which converted it into a bathyscaph, *FNRS-3*. The Piccards moved to Italy to secure funding for and to construct a new deep ship. Their substantial financial, material, and moral support in and from the city of Trieste prompted them to name their new craft in its honor.

With a sphere forged (making it stronger than casting) at a steel works in Terni, Italy, the craft was launched August 1, 1953 near Naples. The first dive occurred August 12, to 3,570 feet. The Piccards made several dives together, with a final dive for Auguste September 30 to 10,390 feet. The plan was for Jacques to continue as pilot, with one observer. A few dives were made in 1954, but with no source of funding, there was none in 1955.[10]

At that point, a fortuitous meeting occurred: Jacques Piccard traveled to London for speaking engagements and to appear on a TV show, following which he met with a group of engineers. The group included a U.S. Navy scientist on temporary duty at the Office of Naval Research in London. ONR for some time operated facilities in Tokyo and London, by way of gathering intel on research in Europe and Asia with potential value for the Navy. Over the years, a number of Point Loma lab scientists held these one-year assignments.[11]

Dr. Robert Dietz, who had worked at the Navy Electronics Laboratory (NEL) for eight years, taken a year off to study and then assumed the ONR assignment, saw in Piccard's underwater craft a potentially history-changing invention. Following a dive with Piccard, he reported to his ONR superiors and talked the chief scientist into traveling to Italy for a first-hand view. That stimulated an invitation for Piccard and Dietz to visit Washington to discuss possibilities. The result was a Navy contract with the Piccards, by which Piccard would serve as pilot during a series of dives in the Tyrrhenian Sea near Naples in summer 1957.

Four NEL objectives

One of the dive observers was Dr. Andreas Rechnitzer, selected by NEL to evaluate the craft's potential. In his report, he cited four proposed objectives for

[10] Piccard and Dietz, *Seven Miles Down*, 73.
[11] For example, see Naval Command, Control and Ocean Surveillance Center RDT&E Division *Outlook*, January 14, 1994, 1.

the Navy studies: investigating the deep-ocean environment with the opportunity of *in situ* observation, evaluating the craft as a research tool, encouraging modification or further development of bathyscaphs, and examining the uses of bathyscaphs for naval uses such as submarine rescue or a deep-depth submarine.[12]

He described the craft as "a self-contained, surface-independent, navigable diving chamber, accommodating two people, instruments, and power supply, with a possible submersion time of more than 48 hours." Although the primary interest was in underwater acoustics, he noted inclusion of study in the "biology, geology, and physics of the deep ocean—these investigations contributing directly to the main program through the identification of sound sources and the determination of the sound-transmission qualities of the ocean and the bottom."

Despite contract specification of fifteen dives, Piccard made twenty-six, providing a large number of scientists an opportunity to experience the deep ocean.

Rechnitzer summarized,

> The bathyscaph's primary attribute is that it permits visual observation of the deep sea. Observation of the poorly understood deep-sea realm permits identification of organisms and physical phenomena. Future investigations of a quantitative nature can be effectively planned once the phenomena present are better identified.[13]

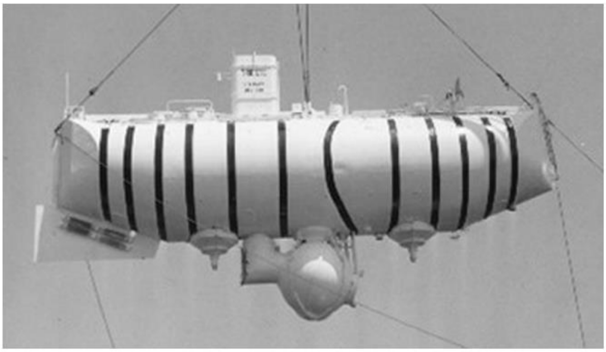
Recognizing its value to fundamental deep ocean research, the Navy negotiated with the Piccards for the craft. While the scientists hoped for a three-year lease, the Navy held out for outright purchase. The Piccards finally agreed in order to gain funds for a new bathyscaph, according to the son.[14] Contracted to serve initially as pilot and to train Navy-selected individuals to operate the craft, Jacques Piccard was pleased the Navy planned to locate *Trieste* at Rechnitzer's lab, NEL in San Diego, where deep water was only fifteen miles away, rather than a hundred or more. He was also pleased to learn Andy Rechnitzer would be in charge of the bathyscaph's research program, calling him "a fine ichthyologist and marine biologist. A pioneer in the scientific use of scuba diving, here was a man who could outperform a fish in its own environment."[15]

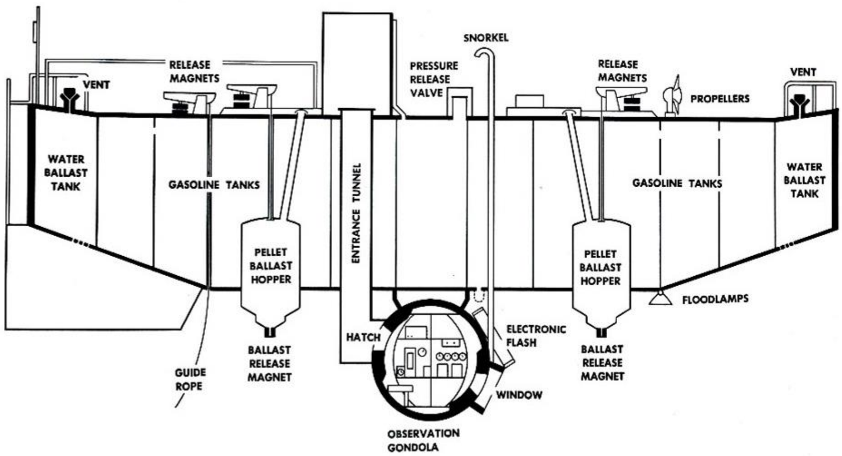
Trieste arrived in San Diego in September 1958, accompanied not only by

---

[12] Dr. A.B. Rechnitzer, "The 1957 Diving Program of the Bathyscaph Trieste," NEL Report 941, 28 December 1959, 3.
[13] Rechnitzer, "The 1957 Diving Program of the Bathyscaph Trieste".
[14] Piccard and Dietz, *Seven Miles Down*, 115.
[15] *Seven Miles, Down*, 84.

Jacques Piccard, but his topside engineer, Giuseppe Buono. A native of Castellammare di Stabia near Naples, Buono worked at the shipyard there, and had supervised deep ship construction under the direction of Auguste Piccard.[16] He was the only third individual with the pilot and observer on the superstructure of the bathyscaph in the final moments before a dive, ensuring all equipment was working properly and sealing the hatch as the last step prior to the dive. Following the Deep Dive, Jacques Piccard would return to Europe. Buono elected to remain with the craft, working as a technician on various projects at the Point Loma laboratory after the *Trieste* era, until his retirement from U.S. Civil Service in 1983.





Schematic shows the major components of the bathyscaph *Trieste,* which arrived in San Diego in September 1958 to begin a series of dives in the local area under the management of NEL.

[16] Naval Ocean Systems Center *Outlook*, February 15, 1980, 3.

With the arrival of the bathyscaph, Andy Rechnitzer formed a team to operate and maintain the craft. He contacted the commodore of Submarine Flotilla One, located a mile south of NEL's waterfront, requesting two submarine officers and a handful of enlisted personnel for his team. The commodore forwarded the request to all West Coast subs; there was only one volunteer, so an officer temporarily assigned to his staff also raised his hand—Lieutenant Don Walsh.[17]

The first U.S. Navy dive of its new bathyscaph took place in San Diego harbor on December 17, 1958. Following a dive required by higher authority to satisfy a news agency, over the next six months there were two shallow test dives, two biological observation dives with Andy Rechnitzer as observer, and a "technical" dive in which Piccard began to instruct Lieutenant Walsh in operating the craft. Additionally, conducted at the end of May,

> The most scientifically productive dive was made into San Diego Trough with K.V. Mackenzie of NEL. Using two special Bureau of Standards sound-velocity meters, he hoped that *in situ* measurement would improve the precision to which underwater sound velocities are known.[18]

None of the efforts approached the 10,000-foot-plus dive made by the Piccards in September 1953, but there was an inescapable curiosity when another such venture might be attempted, perhaps one with substantially greater stakes. Fairly early in their association, at an international meeting of oceanographers in Sweden, Jacques Piccard and Robert Dietz had discussed an "assault" on the Challenger Deep, named for the British ship that discovered it and reputedly the very deepest spot in the world's oceans. They would later recall, "It would be the last great geographic conquest."[19] In an interview four decades later, Andy Rechnitzer would explain his thoughts as scientist in charge of the craft: "I knew we were going to be challenged continually to set new depth records with Trieste. I decided to just do the deep dive and get it over with so we could then go do the serious oceanographic research that interested us and the Navy."[20]

---

[17] The preceding paragraph is a brief summary of Walsh's, "In the Beginning…" MTS *Journal*, 9.
[18] *Seven Miles Down*, 124.
[19] *Seven Miles Down*, 131.
[20] "Scientist-in-charge of bathyscaphe Trieste passes away," SSC San Diego *Outlook*, September 23, 2005, 2-4, citing an interview in 2000.

New sphere forged

Somewhat coincident with arrival in San Diego, the Office of Naval Research contracted with Piccard to obtain a new pressure sphere. He acknowledged, "Even then, there was no firm assurance that we were pointing toward Guam and the Challenger Deep. It would, however, provide us with the capability of making such a dive."[21]

Piccard traveled to Europe to negotiate with the Terni company, which had forged the original sphere; they declined the opportunity. After a survey of potential sources, Krupp Steel Works in Germany was contracted to forge one. The sphere, fashioned of a central ring with two end caps, was delivered to San Diego in April 1959 and placed under wraps. On June 5, the bathyscaph collided with its tender, requiring it be dry-docked for inspection and repair. Since it was already out of the water, it was decided to install the new sphere. On July 10, 1959, NEL CO and Director Captain John Phelps mailed an official request to the Chief of Naval Operations for the Deep Dive attempt. It was quickly approved.

Based upon an observation by Dietz that free-swimming sea denizens such as fish, sharks, and whales were termed "nekton," and that *Trieste* with its limited propellers was also, the Navy assigned the designation Project Nekton to it.

With the new sphere installed, *Trieste* made two dives in September. The first was a shallow dive to ensure appropriate operation of the sphere and a new float constructed to increase its gasoline capacity by six thousand gallons and its shot load by five tons, both requirements for descending to and returning from much greater depths than ever attempted. The second one allowed Andy Rechnitzer to perform some biological observations in relatively shallow water.

The craft and its crew then were transported to Guam, with the first dive in Apra Harbor occurring on November 4. Over the next two months, almost a dozen dives were made, two of them resulting in new world ocean-depth records: Dive 61, with Piccard as pilot and Rechnitzer as observer on November 15, 1959—18,150 feet; and Dive 69, with Piccard as pilot and Lieutenant Walsh as observer on January 8, 1960—22,540 feet in the Mariana Trench.[22]

---

[21] *Seven Miles Down*, 135.

[22] A.B. Rechnitzer, "Summary of the Bathyscaph Trieste Research Program Results (1958-1960)," NEL Report 1095, 2 April 1962, 8 & 9.

An old adage promises, "If something can go wrong, it will." One can only imagine the painstaking planning required to place two men on the bottom of the sea, seven miles down, with pressure amounting to sixteen *tons* per square inch, and bring them back safely. The things that might go wrong—equipment that might fail, people working under intense pressure who might make critical mistakes, the sea which might exercise its right to do whatever it pleased—suggested such an undertaking might be not just difficult, but perhaps impossible. Nevertheless, the small team of seven civilians and two junior naval officers from NEL, two foreign nationals, and four Navy enlisted set out to demonstrate it could be done.[23]

During the first Mariana Trench dive, there was a "slight shift" of major components of the sphere when the epoxy resin bonding glue failed, with only minor water leakage, but under the circumstances suggesting the potential for disaster. Undeterred, the team worked the problem, supported by the Naval Repair Facility at Guam, and satisfactory repairs were completed. The list of those not authorized to receive information on the venture, principally the news media, expanded, according to Walsh: "Also we decided not to bother our masters at NEL with this particular situation. Most certainly this would have been the end of Project Nekton."[24] He credited the first Navy enlisted man assigned to the team, Senior Chief Machinist John Michel, with "a brilliant although unorthodox fix," using metal bands, automotive gasket compound, and rubber strips.

With the year-end holidays over, Piccard and Walsh made the trench dive to 22,540 feet, demonstrating convincingly the repaired craft was ready for the Deep Dive. While a U.S. Navy tugboat carrying Piccard and Buono plodded at five knots toward the dive site towing the bathyscaph, Rechnitzer and Walsh aboard a destroyer escort steamed to the spot rapidly for the final determination of the exact location. Since the ship's depth sounder was unable to "see" that far down, the NEL fish expert located it using small blocks of TNT and a stopwatch to time the distance traveled by acoustic energy from the explosions.

One final obstacle had to be overcome: as Lieutenant Walsh and Dr. Rechnitzer prepared to dive, Piccard cited a clause in Navy contract allowing him to participate in any "different or unusual" dives. There was no denying this was such a dive, and Piccard was taking it. Although Rechnitzer was a naval reservist, the decision was made to send the active-duty officer, Lieutenant Walsh.

[23] NEL *Calendar*, 29 January 1960, although it is mistakenly printed as "1959", 1.
[24] Walsh, "In the Beginning…" 11.

Rechnitzer took the disappointing decision in stride, including thwarting a last-minute executive decision to scrub the dive.

According to Senior Chief Michel, Walsh and Piccard were ferried out to the bathyscaph in heavy seas (Walsh in his MTS *Journal* article says "sea state six to seven"; Piccard in his book reported conditions so bad waves swept away the telephone and badly damaged the tachometer on the craft), but Jacques decided to dive. On board the escort ship, Rechnitzer and Michel had little to do now until the dive progressed, so they went for a cup of coffee. Shortly afterward, the radio operator handed the scientist in charge a message that had come in; it was from his boss, the commanding officer and director of NEL, instructing him to cancel the dive and come home. Some years later, Senior Chief Michel recalled his own reaction as "fit to be tied," but his companion's as "nonplussed." Rechnitzer suggested getting more coffee, which they did, engaging in general conversation about Project Nekton and related subjects. After some time had elapsed, Rechnitzer showed up at the radio room and instructed the operator to send a message to the NEL director *Trieste* was passing the 20,000-foot depth.[25]

"A flatfish and a beautiful red shrimp"

The various natural and man-made obstacles dealt with, Piccard and Lt. Walsh headed toward the deepest ocean bottom, seven vertical miles of inky blackness below. A small negative encounter with the thermocline was managed easily by dumping a little gasoline, and they descended at a reasonable rate. It took nearly five hours to reach the bottom. As often occurred, the force of the landing stirred up clouds of sediment. In spite of that, to their substantial surprise anything could live at the extreme depth and pressure, they saw a flatfish, "resembling a sole, about 1 foot long and 6 inches across," and "a beautiful red shrimp."[26] Unfortunately, circumstances (the extreme time for a dive, limited daylight of a winter afternoon on the surface coupled with a high sea state) necessitated a short bottom time. After twenty minutes punctuated by a congratulatory handshake, the sixteen tons of ballast were jettisoned, and a three-and-a-half-hour ascent began.

[25] Master Chief John Michel, USN (Ret.), "In the Trenches…Topside Remembrances of the Chief of the Boat, DSV Trieste," Marine Technology Society *Journal*, Volume 43, Number 5, Winter 2009, 21-22.
[26] *Seven Miles Down*, 173 & 175.

On the surface, the craft was rigged for towing back to Guam, and the principals—Rechnitzer, Lieutenant Walsh and his assistant Lieutenant Larry Shumaker, Jacques Piccard—were hustled back to the island, where an aircraft waited to whisk them to Washington, D.C. for a round of honors. The first was the most significant, as President Eisenhower presented the nation's highest civilian honor—the Distinguished Civilian Service Award—to Rechnitzer, the Legion of Merit to Lieutenant Walsh, the Navy Commendation Ribbon to Lieutenant Shumaker, and the Distinguished Public Service Award to Piccard.

After the "Deep Dive," President Eisenhower honored (l-r) Jacques Piccard, Lieutenant Don Walsh, Dr. Andy Rechnitzer, Lt. Larry Shumaker.

The president's remarks included,

> Their marked professional skill and resourcefulness, their scientific studies and courageous efforts while conducting operations at great personal risk, culminated on 23 January 1960 in a dive by the bathyscaph TRIESTE to the unprecedented depth of 37,800 feet, the deepest spot on the ocean floor known to man… This, the first penetration of the deepest part of the ocean, impressively demonstrates that the United States is in the forefront of oceanographic research.[27]

[27] NEL *Station Journal*, 4 February 1960 and NEL *Calendar*, 5 February 1960, 1. The team recognized the depth meter was in error due to calibration in Switzerland using distilled water rather than seawater, and requested recalibration. The presidential ceremony was February 4, before accurate depth calculation had been made. After the Naval Weapons

As noted early, Piccard went home after the various recognition ceremonies. The scientist in charge and the two lieutenants returned to Guam to pursue Project Nekton II, a couple of test and training dives followed by five which Andy Rechnitzer had visualized at the beginning of the effort—sound velocity measurements. Mostly "shallow" dives, one on July 1 was to a depth of nearly 19,000 feet. As reported in the "popular" press:

> Amid the gains to be made by prowling around where pressures are measured by tons rather than pounds is further contribution to the vast knowledge about deep scattering layers and thermoclines which frequently are used by submarines to avoid detection by surface craft.[28]

The team and *Trieste* returned to San Diego in July, where the craft was to undergo extensive refurbishment, remaining out of the water for more than a year.

After world record, time to document

After months far from home, Andy Rechnitzer finally had time to sit down at his desk to document formally what had been accomplished:

> The scientific observations and measurements made during Projects NEKTON I and II yielded valuable new data on sound velocity; temperature and salinity structure; water clarity; bioluminescence; the distribution of suspended particles and plankton; water current at great depths; sea floor features; and the general environmental conditions in the deep Marianas Trench.[29]

Recognizing and appreciating the bathyscaph's value, he also saw shortcomings, recommending the Navy "develop a deep submersible research craft more versatile" and "evaluate the usefulness of deep submersibles as platforms for acoustic detection equipment and naval ordnance."[30]

A series of dives began in September 1961, with some of NEL's major scientific investigators taking advantage of this exceptional opportunity to study

---

Plant in Washington, D.C. recalibrated the meter, oceanographers from Scripps Institution of Oceanography and the National Science Foundation "applied corrections for salinity, compressibility, temperature, and gravity. Agreement was reached that the depth attained was 35,800 feet…," according to *Seven Miles Down*, 173.

[28] "Exploring the Ocean's Greatest Depths," *Popular Mechanics*, February 1960, 116.

[29] Dr. A.B. Rechnitzer, "Summary of the Bathyscaph Trieste Research Program Results (1958-1960)," 1.

[30] Rechnitzer, "Summary…" 2.

geology, biology, and underwater acoustics in the depths. The geographical area they studied, near the San Diego coastline, was interesting in itself, as it was "neither deep sea nor a continental shelf. Unique in the world, it is instead a foundered ancient shelf 105 miles across with numerous shallow banks and basins as much as 1,000 fathoms deep. To describe it, a special name was coined, a 'continental borderland.'"[31]

The operators also changed, as Lieutenant Commander Don Keach and Lieutenant George Martin relieved Walsh and Shumaker. The one constant was Giuseppe Buono, whose knowledge and experience made him almost impossible to replace. While plans progressed to build a new float for *Trieste*, the next set of research dives was initiated on April 4, 1963. It was to be followed by a second dive a week later, which was cancelled based on highly classified message traffic relating to a disaster at sea: the lead boat of a new class of nuclear attack submarines, USS *Thresher* (SSN-593), failed to surface after a deep-diving test off the coast of Massachusetts, and was presumed lost. The Navy summoned every asset at its disposal to the site, some 270 miles east of Boston, including the only one of those assets that could take people to the 8,400-foot depth there: *Trieste*.

According to Lieutenant Martin's account, it would be more complex than the usual diving routine:

> The Trieste was transported to Boston, Massachusetts, and made ready for not just one dive but a series of consecutive dives requiring a complete replenishment-at-sea operation after each one. This had never been accomplished before and required a great deal of work to perfect. The at-sea replenishment was mandatory in order to avoid the long tow back to port and then return to the operating area. This would save time and wear on the fragile bathyscaph. The replenishment consisted of charging the storage batteries, replenishing nine tons of steel ballast and refilling the maneuvering tank with gasoline to be expended, replenishing the life support system with new oxygen and carbon dioxide absorbent.[32]

The bathyscaph made five dives (numbers 119-123), with Lieutenant Commander Keach and Lieutenant Martin alternating as pilot and NEL oceanographer Kenneth Mackenzie as observer on all five.[33] On two of the dives they discovered and photographed debris from the lost submarine. After two months ashore for maintenance and equipment upgrade, *Trieste* returned to the site

[31] *Seven Miles Down*, 121.
[32] Lieutenant George W. Martin, "Trieste: The First Ten Years," *U.S. Naval Institute Proceedings*, Vol. 90, No. 8, August 1964, 58-60.
[33] On dives 122 and 123, June 29 and 30, 1963, a second observer was somehow jammed into the small cabin, identified on the log only as "Cash" and "Andrews."

in August and made five more dives, finding significant pieces of wreckage and recovering a section of pipe that ensured positive identification.

The Navy recognized the effort by awarding the Navy Unit Commendation to *Trieste* (the first time a research vessel had been presented this award) and to the military personnel— Lieutenant Commander Keach, Lieutenant Martin, and eight sailors: ENC J. Norman, EMC F.D. Barnett, ETC J.A. Devoe, ET1 R.D. Legg, SF1 B.F. Gordon, SF1 A.G. Wigdahl, SOS2 N.D. Smith, and ETN3 G.L. Hersh. Notably, for the first time in the Navy's history, the NEL civilians involved—scientist in charge Kenneth Mackenzie, Giuseppe Buono, Manuel M. Medina, Archie Davis, John Sneed, William H. Armstrong, and John R. Houchen, Jr.—were also awarded the unit citation and authorized to wear the ribbon.[34]

Although *Trieste* had performed exceptionally well on 128 dives, including four to hadal depths and ten to the *Thresher* debris field, the bathyscaph was failing. Upon return to San Diego, a new float was manufactured, and the craft was rechristened.[35] The new float was sixty-seven feet long (vice about fifty-nine for the original) and several feet wider. It was also teardrop-shaped to allow safer, faster towing (ten knots rather than four). With the critical interrelationship between flotation and ballast, the larger float was required to store an additional seven tons of disposable ballast and a corresponding increase of gasoline to 46,000 gallons. To prevent a catastrophic failure related to that huge amount of gasoline, the new float was equipped with eighteen storage tanks vice the original nine.

The newly refurbished craft was rededicated in ceremonies on January 17, 1964.[36] After a half-dozen dives to test new equipment and train new pilots, NEL scientists were provided access for a series of research dives. In June, the craft was moved to the East Coast for follow-up dives on the *Thresher* wreckage. Five dives (plus an additional investigation with a towed camera array) documented the sub's stern planes and the sail with the numbers "593."

In March 1965, the craft was transferred to the operational Navy's Deep Submergence Systems Project.[37] At this point, a series of murky adventures,

---

[34] NEL *Calendar*, 18 and 25 October 1963.
[35] A contest was held among NEL employees for a new name, with "Nekton" the winner. NEL *Calenda*r, 2 August 1963, 1. However, when it was learned the Navy Unit Commendation for the craft, its operators, observers, and support team for the *Thresher* operation could not be retained if the name changed, the "II" was added and that was it.
[36] NEL *Calendar*, January 17 and 24, 1964, 1.
[37] Will Forman, "From Beebe and Burton to Piccard and Trieste," Marine Technology

certainly obscured by security considerations, ensued. Final involvement of the Point Loma lab occurred in the late 1980s, when Lieutenant Karin Lynn, a Civil Engineering Corps officer assigned to what was then the Naval Ocean Systems Center, undertook, as a favor, the disposition of the last version of *Trieste II*, resting idly on a Point Loma pier. She arranged to have it shipped to the U.S. Naval Undersea Museum in Keyport, Washington, where it is currently on display.[38]

New York *Times*, April 15, 1960, P. 1: "POLARIS A SUCCESS IN UNDERSEA TEST" By Bill Becker. "San Clemente Island, Calif., April 14—The Polaris missile passed an important underwater launching test today in a twenty-two-second controlled flight at this Navy test range… Nearly 100 newsmen, photographers and other observers watched the launching from about 5,000 feet away… The moment the missile burst from the water its solid-fuel propellant ignited in flames and the missile soared vertically for about nine seconds… San Clemente Island, which lies fifty miles off the southern California coast near San Diego, has been the West Coast center of Naval Polaris operations since March, 1958."

"The most significant contribution China Lake made to the nation's nuclear program was in the development of the Polaris fleet ballistic missile system," wrote Volume 4 author Cliff Lawson.[39] It was a contribution stimulated by past association, one that almost didn't happen, as the Navy found itself nearly positioned out of America's race to counter Soviet building of a nuclear arsenal.

A previous chapter introduced Dr. Bruce Sage, "the boss of the pilot plants." Sage was a Caltech professor of chemistry who set up the main extrusion facility for the rocket program. He also was instrumental in developing the physical structures allowing the significant Caltech/Naval Ordnance Test Station contribution to the development of the atomic bomb. As noted in that chapter, Sage routinely worked sixteen-hour days and usually held the equivalent of two or three jobs. While admiring his work ethic and selecting him for the top management position of assistant technical director for engineering, NOTS Technical Director Dr. L.T.E. Thompson was concerned one of his most valuable managers would

Society *Journal*, Winter 2009, Volume 43, Number 5, 33.

[38] Captain Karin Lynn, USN (Ret.) email copied to Tom LaPuzza, March 11, 2013; museum's Ron Roehmholdt email to Tom LaPuzza, February 14, 2018.

[39] Cliff Lawson, *The History of the Navy at China Lake, California, Volume 4: The Station Comes of Age* (China Lake, California: United States Navy Naval Air Warfare Center Weapons Division, 2017), 106.

depart the station, perhaps with insufficient notice to fill adequately the substantial gap that would create. To that end, Thompson cultivated an ongoing relationship with a Bureau of Ordnance naval officer with an impressive record of achievement during World War II. Commander Levering Smith had demonstrated substantial leadership during the war. Afterward he was ordered to BuOrd to oversee production of propellant for guns and rockets. Of critical interest to Thompson was the fact Commander Smith had evinced a decided bent toward engineering duty, to the incredible length he actually turned down command at sea, the pinnacle of success for a surface warfare officer, to pursue work more indicative of naval research than naval operations.

When Smith accepted Dr. Thompson's invitation to begin his engineering duty at NOTS in September 1947, he was detailed as deputy in the Explosives Department, managed by Dr. Sage. The fact the two men were long-time friends somewhat countered the anomaly of a military officer filling a clearly civilian position. When Thompson selected Sage as assistant TD, he continued as department leader in name, but Smith became in essence the department head.

As a priority Smith set for himself, he determined to improve NOTS funding requests to the Bureau of Ordnance, his last duty assignment. According to China Lake historian Elizabeth Babcock, "Smith's BuOrd experience had given him valuable familiarity with the Navy's R&D planning system, which in 1948 was simple and functional…"[40] Major change was coming, however, with the establishment of the office of Secretary of Defense, but until that occurred "Levering Smith was there to help China Lake's technical leaders navigate the existing planning structure more smoothly."

Justifying the confidence of Thompson (who would present him one of his first namesake awards[41]), Smith was promoted to captain by the Navy and to associate technical director by Thompson when, as anticipated, Sage departed China Lake. Smith played a critical role in upper echelons of NOTS management for nearly seven years, before he was transferred on very short notice to another missile site in the desert, White Sands Proving Ground in New Mexico.

As Levering Smith settled into his New Mexico assignment, events were underway in the nation's capital that would ensure him the admiral's stars he had more or less given up when he chose engineering duty. Recognizing the Soviet

---

[40] *Magnificent Mavericks*, 13.
[41] *Magnificent Mavericks*, 504.

Union was making substantial progress in ballistic missile development, President Eisenhower in 1954 created a committee, chaired by Dr. James R. Killian, Jr., to study that development worldwide and assess the strategic implications of such programs. Their report included recommendations which basically emphasized immediate focus on Intermediate Range Ballistic Missiles (IRBMs) and longer-term development of Intercontinental Ballistic Missiles (ICBMs),

Reacting to that, with some apparent sense of caution, Secretary of Defense Charles Erwin Wilson limited pertinent projects to three Air Force missiles—Atlas and Titan, both ICBMs, and the land-based IRBM Thor missile—and a Navy support system to adapt the Army's land-based Jupiter IRBM for launch at sea.

The initiation of major weapon system development is traditionally and reasonably a time of discussion, debate, confusion, and sometimes chaos, as various parties seek to champion their concepts for system design. The race to establish a credible deterrent to potential Soviet nuclear weapon use seemed in the bag for the Air Force, which reasonably assumed its bombers would dominate strategic weapon delivery for years to come. In addition to those bombers which delivered the first nuclear weapons in history, the Air Force had proposed its Atlas ICBM program in 1950 and subsequently begun work on its improved Titan rockets. Before mid-decade, it was accelerating missile development.

Somewhat in competition with those programs, a team led by Wernher von Braun had begun developing the Jupiter missile for the Army in 1954. A compromise to the Air Force-Army rivalry authorized the Air Force to develop Thor, substantially similar to the Army missile, while the Army continued Jupiter development on behalf of the Navy.[42] Unfortunately, a number of influential Navy officials failed to see the value of ballistic missiles for the sea service. At the same time, the Office of Naval Research/Naval Research Laboratory was interested in high-altitude rockets, while the Bureau of Aeronautics pushed for additional development of its supersonic Regulus I for surfaced submarine launch, and the Bureau of Ordnance sought a ballistic missile for submerged submarine launch. With competing interests, or lack of it, among prominent naval authorities, particularly for ballistic missiles, these efforts plodded along with little progress.

One of the more immediate actions was a Navy Bureau of Aeronautics invitation to appropriate industrial firms and government laboratories for proposals on ballistic missile design, specifically one to be launched from a ship or

[42] http://www.astronautix.com/j/jupiterirbm.html visited May 13, 2020.

submarine. Although he did not report to him, the BuAer chief did alert Chief of Naval Operations Admiral Arleigh Burke, about the planned invitations. The time frame between the notification and invitation mailing is unknown, nor is it known how long Admiral Burke deliberated before replying; what is certain is that by the time he responded with an order to discontinue the effort, the invitations had abeen mailed. The Bureau of Ordnance protested, setting off significant competition between the two bureaus. Both had reasonable credentials to lead, and given the potential large-scale scope of it, the ensuing competition was fierce.

SecNav establishes Special Projects Office

In 1955, the Secretary of the Navy side-stepped that competition and established the Special Projects Office (SPO) "as a separate office outside of the bureau structure to solve problems associated with ship launch of Jupiter-S, a huge sea-based solid-propellant missile to be designed…as a joint Army and Navy program."[43]

Rear Admiral William F. Raborn reported at the end of November to head the office. Already on hand was Captain William A. Hasler, the NOTS Pasadena officer-in-charge from 1947 to 1952. Acknowledging the critical importance of the office and its mission, the CNO gave Raborn authority to select the cream of the crop of Navy personnel for his project. With that authority (facetiously termed "Red Raborn's hunting license") in hand, he selected another NOTS alumnus, Levering Smith, to head SPO's Propulsion Branch.

Although the sea service was substantially behind the power curve, the decision to adapt the Army's Jupiter missile for naval use at least kept Navy involved. It did, however, face substantial challenges, notably a lengthy development period, with missile testing in 1958, deployment on a freighter in 1960, submarine test-firing three years later, and deployment aboard an actual missile submarine in 1965. And some considered that as "virtually impossible."

Another major challenge was that Jupiter's land-based status allowed a size rivaling Air Force rockets (more than fifty feet long and weighing fifty-five tons) and a propulsion system based on high-energy liquid fuel. The Navy's rational

[43] *Magnificent Mavericks*, 331.

aversion to liquid-fueled weapons on ships and submarines required a new design based on solid propellant. The new missile was titled Jupiter-S, since it would go to sea. The contractor proposed a missile forty-three feet long, an improvement, but it swamped the scales at eighty-four tons! There was substantial *angst* at SPO, and probably even more in the minds of Navy operators at sea, related to a submarine that could carry such a weapons payload.

Much of the additional weight came from the solid propellant design, the technology for which was fairly limited. That provided Levering Smith the opportunity—and probably in his mind the responsibility—to seek alternatives to the contractor concept. While his associates devised plans to modify a submarine to carry and launch four of the massive Jupiter-S weapons, Smith reached back to NOTS and requested his former colleagues review the proposed design.

The Weapons Planning Group took on the request, formalized as Project Mercury, and responded relatively quickly that modifying the Jupiter-S design was not workable. Results from the quick study suggested, however, a missile in the 30,000-pound range, powered by solid propellant, was feasible. It would have several other advantages, most significantly the possibility it could be developed much more quickly than the near-decade quoted in the first planning estimates.

One of the principal planners was Frank Knemeyer, whose lengthy and highly productive career at China Lake included an early assignment in the Research Department's Ballistics Division. Four decades later, he would pen an article for the China Lake Museum Foundation titled "Concept Formulation of the Navy's FBM."[44] In it he would describe the follow-up to the initial study on the Jupiter-S, and proceed to discuss "a more intensive and detailed study to project what advanced technology in every system component would provide in the desired development time scale."

Knemeyer discovered in Lawrence Livermore Lab reports information that led him to conclude integration of nuclear and missile technology could eliminate a separate re-entry heat shield, resulting in a significant reduction in weight and size. In a fairly short time, the group developed a "concept of a far lighter missile, reducing the warhead, guidance unit, and controls in size and integrating the warhead case with a lightweight beryllium heat shield for a substantial weight savings."[45]

---

[44] Frank Knemeyer, *The China Laker,* Vol. 9, No. 4, Fall 2003.
[45] *The Station Comes of Age,* 107.

SPO management was enthused about the concept, but feared program cancellation if they proposed a departure from use of a modified Jupiter. They opted to continue development consistent with the original 1958-1965 schedule, but requested additional study by NOTS. Under Project Atlantis, two planners were asked to determine damage levels required to preclude/cripple enemy response, thus providing a "credible" deterrent to Soviet aggressive moves.

The Air Force was designing its missiles with massive warheads to impart equally massive destruction on well-protected enemy weapons launch sites. The NOTS planning group offered a more studied approach. Group members Dr. Glover S. Colladay and David S. Bloom were tasked to determine a reasonable level of lethality, one based on deterrence. That central concept of the NOTS approach would influence the entire U.S. policy on nuclear weapon use.

Since the only examples of nuclear attacks were the two bombs dropped on Japan, Colladay and Bloom considered instead the effect of catastrophic natural disasters on major cities. With the resultant mathematical model in hand, they applied that to damage in Hiroshima and Nagasaki. Not only was there close agreement with their calculations, but, more importantly, the results indicated the damage envisioned could be effected with low-yield warheads.

The pair conducted a detailed study of more than three hundred Soviet cities, based on their analysis the appropriate destruction to disrupt effectively the functioning of those cities was to kill one-third of the population and wound another third. Extrapolating to the larger picture, they determined achieving that level of destruction in twenty-five cities "would essentially wipe out Soviet governmental control."[46] And that could be accomplished, they believed, with a one-megaton device targeting each city.

As reported in Volume 3 of the China Lake history, "Central to Colladay's and Bloom's study was the concept of deterrence rather than a counterforce posture. The idea, still central to U.S. nuclear policy, was to avoid war by convincing the enemy that an attack would result in disastrous consequences."[47]

Military officials, however, continued in their belief much larger warheads were required.

In the summer of 1956, a National Academy of Sciences study requested by

---

[46] *Magnificent Mavericks*, 334.
[47] *Magnificent Mavericks*, 333.

CNO Admiral Burke addressed concerns about the growing Soviet submarine fleet. (The study was conducted at the Woods Hole Oceanographic Institution in Massachusetts, about a mile from a prominent geographic feature called Nobska Point. The formally titled "The Implications of Advanced Design on Undersea Warfare" was known more familiarly as the "Nobska Study.") Since the study was to address not only conventional ASW but also the strategic use of the ocean environment, Dr. Frank E. Bothwell, who headed the NOTS Weapons Planning Group, was invited to attend. (Also in attendance were Carl Eckart of the Marine Physical Laboratory and Roger Revelle, now a civilian scientist working at Scripps.) Bothwell persuaded the group to include submarine-launched ballistic missiles in its study. One conclusion reached after much discussion was the NOTS calculations of appropriate weapon range, weight, and warhead yield be adopted, instead of the Jupiter-S plan. Those calculations had been reviewed and verified by scientists at the Lawrence Livermore National Laboratory; an official of that organization personally expressed confidence in them to study participants.

The study panel's subsequent recommendation to Admiral Burke was that the Navy develop and field a solid-propellant 1,500-mile missile weighing 25,000-30,000 pounds with a low-yield warhead, deployed in a fleet of submarines.

Over the 1956 Labor Day weekend, SPO officials Rear Admiral Raborn and Captain Levering Smith hosted a meeting in Washington, D.C., inviting NOTS Weapons Planning Group officials (Dr. Bothwell and Don Witcher, who had conducted the negative analysis of the Jupiter-S) and Dr. L.T.E. Thompson, former NOTS technical director whom Smith had hired as a consultant. Their agreement to pursue development of the smaller missile, coupled with the study panel's recommendation, prompted the CNO to lobby his superiors for that missile. On December 8, 1956, Secretary of Defense Wilson authorized the Navy to proceed, eliminating the Jupiter missile from the program, dissolving the joint Army-Navy missile committee, and allowing the Navy to move ahead on its own. Rear Admiral Raborn, in deference to the sailor's principal navigation standard for hundreds of years—the North Star—titled the new missile Polaris.

In addition to the substantial influence the studies of Colladay and Bloom had on national policy, they would also impact design and development of successive generations of submarine-launched ballistic missiles—Poseidon and Trident.

"First total system operational analysis"

Looking back from a perspective of decades leading weapons development, Frank Knemeyer would state in his foundation article: "The task undertaken by China Lake was perhaps the first total system operational analysis conducted on a major weapon system in the Navy," adding that the results influenced the entire "concept, successful development and initial operation" of Polaris.[48]

The implications of a submarine-launched missile were obvious: while Air Force bombers could be shot down, and Army missile silos could be attacked with bombs and missiles, Navy submarines, hidden in the oceans' vast expanse, would be virtually impossible to find, let alone attack. On the other hand, Captain Smith wanted the best of several worlds: not only should a Polaris submarine be able to deliver its weapons from deep-ocean depths, but launch should be possible also in the unlikely event it was on the surface, even if it was tied up at a pier when the order came to fire.

With the military, political, and financial decision-making process concluded, it was now time to design, develop, and test this new missile concept. It was a process that would involve scores of agencies and companies, and thousands of people—government and contractor, military and civilian. And the Naval Ordnance Test Station would find itself right in the thick of it.

Once again Levering Smith exercised his authority and, with ample rationale based on the substantial contributions NOTS had already made, requested the station address a number of critical issues. Although SPO had a prime contractor charged with overall design and development of the system, he sought the expertise of Navy engineers because he knew the NOTS Pasadena Annex

> possessed experience in underwater ballistics unequaled elsewhere in the Navy or in private industry. In spring 1957, the station received an assignment… to develop an underwater launching technique for the Polaris missile, to design and test the missile's launching vehicles, and to examine launcher and missile performance during launching.[49]

Early testing focused on launching the missile in a buoyant container which would ascend to the surface and fire the missile as it broached. NOTS engineers experimented initially with that approach, including some testing at Morris Dam, but abandoned it in favor of propelling the missile to the surface on its own.

---

[48] *The China Laker*, Fall 2003, 12.
[49] *Magnificent Mavericks*, 463.

Although NOTS TD Dr. William McLean favored the capsule approach, suggesting it allowed launch from a significantly greater depth, there were several negatives to that approach. For one thing, employing McLean's own standard logic, it rendered the system more complex. More importantly, a capsule was inconsistent with Captain Smith's desire that surface launch remain an option. The major development contractors also favored the "bare missile" approach.

After initial experimentation with models in a swimming pool at China Lake, testing shifted to another facility resource: San Clemente Island. As discussed in Chapter 7, the island had been employed by the military before World War II for various logistics and training purposes, but in the late 1940s it was in essentially a caretaker status. Beginning in 1951, the Pasadena Annex constructed not only test facilities but also roads and piers, plus some living and recreational facilities. The island's value stemmed from its location a few hours' boat ride from Long Beach, coupled with its relative isolation. The latter, reinforced by Notices to Mariners, ensured not only the safety of the general public but project security as well.

Additionally, from a test viewpoint, specifically photographic documentation, "The high cliffs with deep water close to shore provide a unique test area," observed Howard Talkington, one of the test principals.[50]

While various SPO contractors were engaged in designing electronics and other significant aspects of Polaris, Operation Pop-Up ("experimental subsurface launchings") began on San Clemente Island in 1957. NOTS engineers built a range with a 114-foot pier extending from the east side of the island and concrete launch pads on the sea floor. Measuring equipment was mounted on barges.

Talkington explained the process in his *Proceedings* article, published concurrently with the testing:

> A YFN barge has been converted for use as an instrumentation and monitor barge. More than ninety channels of internal instrumentation are recorded within the missile, and 150 channels of external missile and launcher information are cabled to the monitor barge… Underwater cameras as well as underwater television record the firing…and the initial underwater trajectory.[51]

Although the launcher concept was simple—essentially a powerful, vertical version of a gas-powered torpedo tube—hydroballistics problems were numerous.

[50] Howard R. Talkington, "NOTS, San Clemente Island," U.S. Naval Institute *Proceedings*, June 1960, 93.
[51] *Proceedings* article, 94.

The effect of a powerful release of gas and water on a submarine's hull, for example, was unknown. Such release would occur when a detonating fuze ruptured the diaphragm designed to keep water out of the missile tube until launch. When that occurred, the missile, pressurizing gas, and ejection system gas bubble would emerge in seconds. NOTS personnel and their contractors determined through underwater pressure testing those posed no harm to the submarine hull.

Also of concern were the possible harmful effects of pressure resulting from underwater ignition of the rocket motor. Although that motor was designed to ignite after the base of the missile cleared the ocean surface, it was possible, emerging through a wave crest, the missile base might be still partially underwater at ignition. To determine any hazards to the submarine in that instance, a half-dozen scientists from the Navy Electronics Laboratory on Point Loma were assigned a formal "problem" (what later was called a "project"). They set up a small array of gages around the launcher for four tests in the spring/ summer of 1960. Their conclusion was pressure from underwater rocket ignitions was "at least one order of magnitude smaller than those resulting from diaphragm rupture, and are therefore of no danger to the launching submarine." [52]

Missile failure a concern for launch submarine

Of potentially greater harm was missile failure shortly after launch. While a torpedo tube fired the weapon horizontally, ahead of or behind the submarine, the Polaris missile would be launched vertically, directly overhead, and had to clear the surface by approximately a hundred feet, requiring much more power. Failure of the boost from operating depths or of the missile's on-board rockets to ignite could result in the missile plunging back to the ocean and potentially onto the submarine, its nuclear warhead primed for detonation upon impact. Even the relatively small first version of the Polaris, weighing 28,800 pounds, was a very large, heavy object to boost through the water column and high into the air, and later versions weighed considerably more.

Talkington advised in an interview several decades later,[53]

---

[52] C.T. Thompson, "Underwater Pressures Due To The Launching Of A Polaris Missile," NEL Research and Development Report 1081, 27 October 1961, 17.
[53] Howard R. Talkington interview, "The Role of NOTS Pasadena in the Polaris.

> There were questions of what would happen if you couldn't prove that the launcher worked well enough and you shot such a missile up and it did ignite and fell back and landed on the submarine, which would be running shallow under the water…So we could not have any firings from the submarine until we had qualified the launching system as safe to fire.

He also mentioned the concern that one of the test missiles would fall on and damage the launcher assembly during the evaluation phase:

> We prepared the range at San Clemente Island so the launcher could be brought out there. We placed the pad on the sea floor and all the instrumentation and cameras around it to keep track of what was happening while it was being launched. We also built a scheme for catching the missile after it was shot up. The Polaris missile then as well as Trident now had a gas generator ejection system…so that it didn't actually ignite the first stage until it got out of the water. Certainly not near the submarine. The question was whether you could shoot it out of the submarine and get it through the water-air interface and hold it stable enough to ignite that first stage.[54]

The contractor responsible for the launcher delivered it to the island, and NOTS personnel worked to ensure it operated as required. The first projectiles launched were redwood logs, which underwater cameras recorded emerging from the launcher, heading to the surface. After gaining some experience, the engineers began experimenting with steel cylinders filled with concrete and finally actual missile mock-ups.

Two large structures were built for catching test missiles to avoid damage and prevent their sinking into deep water. The first consisted of two large harbor-defense nets, used for a number of launches, including one on June 19, 1958, when several dozen news media representatives were invited to witness the first public demonstration of the missile. According to the NOTS *Rocketeer*, "To the awed newsmen, 'Operation Pop-up' gave evidence of the feasibility of launching a devastating retaliatory weapon from a submerged atomic submarine."[55] The arrangement, separating the two nets for emergence of the missile from the depths and quickly jamming them closed before it lost momentum and dropped back, required precise timing and presented the possibility of damage to the actual missiles when they replaced logs. To preclude such damage, the second testing structure was a crane, dubbed "Fishhook," positioned above the launch site. It employed a cable attached to the missile's nose, with a take-up mechanism adapted from an aircraft accelerating system to reel in the cable during launch. As the missile rose to the surface, the reel maintained the line with no slack and "when [the missile] came to the apogee, it would just hang there," according to Howard

---

[54] Talkington, "The Role of NOTS Pasadena…" 3.
[55] NOTS *Rocketeer*, June 27, 1958, 1.

Talkington. At that moment, in a live, untethered launch, the Polaris engine would ignite.[56]

That occurred sixty-six launches and a little less than two years after the first media event, when the press was invited to the island again and the nets and Fishhook had been cleared from the scene. A live Polaris missile was launched from the depths; when it reached critical height, the solid-propellant engine fired for five seconds. The missile rose 1,800 feet, trailing fire, before falling back into the sea.[57] In future tests, the booster would burn for a full minute, followed by a second stage that brought the Polaris to hypersonic speeds and powered it as far as 1,380 statute miles. The submarine-launched ballistic missile was a reality.

As noted above, the Navy had come fairly close to being shut out completely of the ballistic-missile deterrence effort. One-time USAF secretary and later four-term U.S. Senator W. Stuart Symington remarked, "… what saved the Navy and much of its combat mission was the Polaris submarine."[58]

As contractors were pushing missile development and NOTS Pasadena and China Lake engineers and technicians were refining launch techniques and the physical shape of the final Polaris nose design, the General Dynamics Electric Boat Division was completing the platform that would carry it. Two days before the start of 1960, USS *George Washington* (SSBN-598) was launched in Connecticut. Incredibly, less than seven months later, and less than a hundred days after the first live launch at San Clemente Island, on July 20, 1960, the Navy's first ballistic missile submarine fired its first Polaris missile. When SSBN-598 steamed to sea on November 15 with a full complement of sixteen missiles, the Polaris weapon system was declared operational. Several years later, the director of the Special Projects Office, none other than Rear Admiral Levering Smith, made a compelling statement about program status: "Current plans call for a 41-ship force of FBM submarines which have been fully funded by Congress."[59]

The major, state-of-the-art Polaris weapon system went to sea a full five years before originally scheduled. Such a feat was unprecedented. The analysis and initial design work at NOTS China Lake and the testing by NOTS Pasadena had

---

[56] Talkington, "The Role of NOTS Pasadena…" 3.
[57] *Rocketeer*, April 22, 1960, as well as the New York *Times* April 15, 1960 article featured at the start of this section.
[58] W. Stuart Symington interview, USAF Historical Research Agency, May 2, 1978, 199.
[59] Polaris Fact Sheet," 1 September 1966.

After "pop-up" testing using the Fishhook fixture at San Clemente Island to determine Polaris missile shape and required underwater boost to reach the surface (left), the first live Polaris firing was conducted at SCI April 14, 1960.

contributed essentially to that success story, but there is absolutely no doubt the leadership of Levering Smith was what made it possible. In congressional testimony about federal laboratories when he was technical director of the Naval Undersea Warfare Center, Dr. William B. McLean made clear his feelings about Smith. Although he was discussing the Anti-Submarine Rocket at the time, he found an example in Smith when he said,

> If we are to have a truly integrated design, a single man must understand what he is trying to create, must be responsible for the choices among the infinitude of alternatives available, and must weave the various elements of the design into the integrated system. Like an architect he must understand the tools of his trade. An outstanding example of such an architect is Admiral Levering Smith in the Polaris program.[60]

[60] Presentation on "Utilization of Federal Laboratories" by Dr. William B. McLean, hearings of the Subcommittee on Science, Research and Development, House Committee on Science and Astronautics, March 27, 1968, 3.

The NOTS role in Polaris development was cited by the Special Projects Office in 1961 with an Award of Merit. Vice Admiral Raborn was still SPO director at the time, but his schedule precluded his delivering the award. He sent an excellent substitute—one of his senior staffers, Captain William Hasler. During the morning ceremony at China Lake, the former NOTS Pasadena officer-in-charge told the audience much of his ordnance experience had come from his tour at Pasadena. Which he visited that afternoon to repeat the award presentation.

The station newspaper's next edition reported on specific contributions to the weapon program, including "the development of safe and reliable Polaris rocket motors, the improvement of static testing, and the development, operation and maintenance of the underwater launch facility at San Clemente Island…"[61]

On April 1, 1964, an official of SPO presented the Pasadena Annex with a Polaris flag, symbolizing its substantial role in missile development and testing.[62]

Ongoing Center support for SPO

Over the next decades, NOTS and its successors, particularly the undersea center that in the mid-1960s separated from China Lake and later became one of the two major components of the Naval Ocean Systems Center and eventually today's Naval Information Warfare Center, continued to provide sea range testing and other support to SPO and its follow-on organizations:[63]

--In early 1972, an official of the Strategic Systems Projects Office presented the Naval Undersea Center's Pasadena Laboratory a Poseidon flag for its service as on-site SSPO representative and its operating of the San Clemente Island range for twenty-six contractor launches of the follow-on missile to Polaris, titled Poseidon after the Greek god of the sea, between August 1967 and August 1968.[64]

---

[61] NOTS *Rocketeer*, October 27, 1961, 1.
[62] NOTS *Rocketeer*, April 10, 1964, 6.
[63] As occurred at the Point Loma laboratory, the Washington office responsible for the Navy's strategic weapons changed names several times, beginning in its first years under Rear Admiral Raborn and then Levering Smith as Special Projects Office. The names cited in this section were the official titles appearing on letters of commendation presented to the Center, which received them under various names.
[64] Naval Undersea Center *Seascope*, February 18, 1972, 1.

--In 1990, a senior Strategic Systems Programs official presented a Trident II (D-5 missile) flag to the Naval Ocean Systems Center, this time for several substantial contributions other than sea testing. One was the "baseline architecture for the entire family of missile factory test equipments, and the design and production of the prototype MK 10 Missile Test and Readiness Equipment."[65] This equipment, installed on USS *Ohio* (SSBN-726) class submarines, allowed crew members to test missiles for readiness to launch.

--One of the most critical contributions to the Trident portion of the ballistic missile program occurred when a contractor was unable to produce a charge coupled device (CCD) meeting specified radiation standards. That CCD, for the Mark 6 guidance system stellar sensor, was essential to navigation of the D-5 missile. (Without it, SSBN submarines, armed with weapons they could not fire, were essentially "stranded" at the pier.) Scientists of the NOSC Integrated Circuit Fabrication Facility, which specialized in radiation hardening of electronics, designed and fabricated a CCD that met the specifications, then traveled to the contractor's plant to assist in replicating the process. The SSP flag presenter commented, "You have been the honest technical broker for us in helping get the system on line. One of the key elements in this was Gene Kelley's 'living' with the contractor for six months."[66]

Of paramount importance in the entire endeavor were the contributions by Naval Ordnance Test Station personnel in the very early conceptual stage in development of fleet ballistic missiles, which resulted in a singular capability for the Navy:

> Probably the most technically innovative program in history, Polaris integrated solid-propellant, inertially-guided intermediate range ballistic missiles with nuclear submarines that could remain submerged for months at a time. All of these were new technologies, but the first ship was underway only three years after go-ahead.[67]

One final note: although NEL and NOTS scientists and engineers had some contacts during this time period, such as attending the same technical conferences, collaborative projects were few and far between in the 1960s. On the other hand, several Point Loma people contributed substantially to the Polaris project. As noted above, NEL technical personnel evaluated the safety of the launching submarine and crew: "NEL participated in Operation POPUP [sic] to determine

---

[65] NOSC *Outlook* October 12, 1990, 1, and January 18, 1991, 4.
[66] "NOSC's Trident Contribution Cited," NOSC *Outlook* October 12, 1990, 2.
[67] *Encyclopedia Astronautica*, www.astronautix.com/p/polaris.html visited May 13, 2020.

the effects of Polaris missile firings on underwater structures. Evaluations assured that underwater firings would not endanger submerged submarines."[68]

In early 1961, the commanding officer and director of NEL, Captain Frank B. Herold, was presented the prestigious Legion of Merit for his work on Polaris. The naval officer trained as a radio engineer and serving such duty as shipboard communications officer was cited for outstanding performance of responsibilities in "research and development, testing, and procurement of the fire control and missile guidance systems" for Polaris,[69] which he had handled as head of the Fire Control and Guidance Branch of the Special Projects Office.

A few months later, NEL's assistant technical director for development and engineering, Edwin B. Robinson, was presented a Secretary of the Navy Certificate of Commendation by Vice Admiral Raborn "… in grateful recognition and appreciation of his outstanding service…as a member of the Polaris Missile SSB(N) Steering Task Group Command Communications Committee."[70]

And in 1966, NEL's associate technical director for underseas technology, Dr. Donald Wilson, was awarded the Secretary of the Navy Certificate of Commendation for service as a member of the Polaris Ad Hoc Group for Long Range Research and Development.[71]

The nuclear Navy

This discussion on Polaris cited concern about the tremendous size of the submarine required to carry the envisioned eighty-ton missile. With NOTS efforts at redesign, a strategy emerged for a fleet of smaller submarines carrying smaller missiles that would nevertheless provide desired deterrence. The development of that fleet is outside the scope of this history and far too complex to relate here. It is reasonable, however, to mention briefly the individual driving that development.

Hyman G. Rickover, who immigrated to the U.S. with his parents from his native Poland, attended the Naval Academy1918-1922. During his early career he

---

[68] *NEL/NELC Highlights, A Summary of Technical Achievement, 1945-1970*, TD 104, 30.
[69] NEL *Calendar*, January 13 and February 3, 1961, 1.
[70] NEL *Calendar*, May 19, 1961, 1.
[71] NEL *Calendar*, May 27, 1966, 1.

served in surface ships, but after additional engineering studies he was assigned submarine duty from 1929 until 1933. After a minesweeper command, Rickover transferred to the Engineering Duty Officer community, assigned to the Bureau of Ships. In 1946, he joined a group of officers selected to study nuclear engineering, using his following coincident assignments at the Bureau of Ships and the brand-new Atomic Energy Commission to promote construction of nuclear submarines.

As the first head of BuShips' Nuclear Power Branch, he arranged for competing contractors to pursue different approaches to nuclear reactor development on the technology side, while managing the personnel side by establishing a rigorous selection and education process to provide the Navy with exceptional nuclear-trained officers and enlisted personnel. His indefatigable efforts were rewarded January 17, 1955, when Commander Eugene P. Wilkinson, the boat's first skipper, announced USS *Nautilus* (SSN-571) was "underway on nuclear power."

Fairly coincident with the first operational cruise of *Nautilus,* plans were underway for the Navy to develop a ballistic missile. Less than four years after that first authentication nuclear power could indeed drive a naval vessel, construction began on a nuclear-powered submarine to carry ballistic missiles.

As he himself once characterized his duties, Hyman Rickover was responsible "for directing the initial sea trials of each of our nuclear ships so as to make sure that their nuclear propulsion plants functioned properly and that the officers and men had been well trained."[72]

That was certainly the case when USS *George Washington* put to sea in early 1960. Conscious of his indebtedness to certain influential members of the U.S. Congress (not only for submarine funding, but personally for their influencing the Navy to retain him in uniform although he was passed over for promotion twice), he had written letters to those congressmen advising of the progress of SSN-571. When the first "boomer" (Navy slang for ballistic missile submarine) went to sea, he wrote letters to every member of Congress, plus other federal officials.

Having set the precedent, Rickover continued writing letters upon the commissioning of each of the forty-one Polaris submarines, named for prominent Americans. Based on the latter fact, he included in the letters a brief biography of the individual for whom the submarine was named. Often his letters were printed

---

[72] Admiral Hyman Rickover, USN (Ret.), *Eminent Americans: Namesakes of the Polaris Submarine Fleet* (Washington, D.C.: Government Printing Office, 1972), vii.

in the *Congressional Record*, and many recipients suggested he publish the entire set as a book. In 1968, Congress itself approved funding for the publication, and over the next four years Rickover devoted much of his time to revising and expanding his letters, with substantial research assistance from his wife. In 1972 the Government Printing Office published the results of their collective effort, titled *Eminent Americans*.

Most fittingly, SSN-709 and SSN-795 were both named in Rickover's honor.

NEL *Calendar*, June 10, 1960, Page 2: "Dr. Young Named Society President"

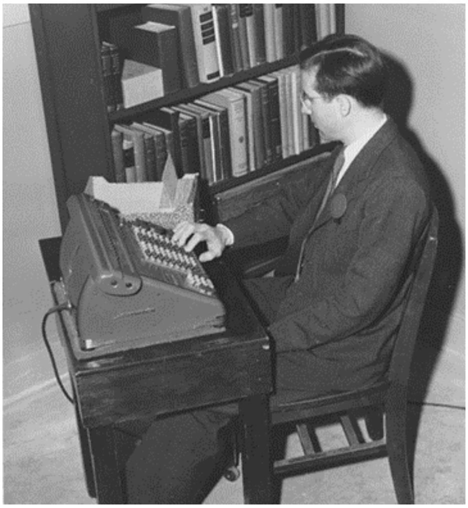
Unlike the New York *Times* and Washington *Post* large-font headlines featured elsewhere in this chapter, it was a small one, about 18 point, not even considered front-page news. The article was brief and to the point, but the implications went far beyond font size or column inches: NEL physicist Dr. Robert W. Young advanced to the presidency of the prestigious Acoustical Society of America (ASA) on June 11, 1960.

During an oral history interview for the society in 1995, Young told a close associate he had joined in 1929. (ASA was organized that year.) At the time, he was beginning his senior year at Ohio University. He noted attendance at 105 society meetings, unable to attend any during his first six years of membership because as a University of Washington graduate student/teaching fellow he earned $50 a month, "barely" enough on which to live, and he had no money for travel.[73]

After earning a Ph.D. from the University of Washington, he worked for a musical instrument manufacturing company, allowing him to pursue his avocation while earning a living. When the threat of German U-boats urgently required the services of acousticians, Young was one of the first scientists personally invited by Dr. Vern O. Knudsen to join the University of California Division of National Defense Research to address that threat. The UCDWR personnel roster confirms Young started working on Point Loma January 16, 1942.

Over the next several years, he researched underwater acoustics, hydrophones for harbor defense listening posts, and sound meters. After the war, the majority of

[73] Dr. Robert W. Young, ASA oral history interview conducted by Daniel W. Martin, November 30, 1995.


Dr. Robert W. Young

"problems" under study and the scientists studying them were transferred to the Radio and Sound Laboratory successor Navy Electronics Laboratory (NEL). A handful of UCDWR personnel transferred to the newly created Marine Physical Laboratory; Dr. Young was one of them. Within a short time, however, he transferred to NEL, initiating a three-decade Navy civilian career. With a major West Coast Navy Lab reorganization in 1967, he was transferred with other oceanographic-related personnel to the new Naval Undersea Warfare Center, remaining with the organization and its successors until his retirement in late 1979. By then he had written, according to his own estimate, 100-150 papers.

At ASA's 148th meeting in 2004, fittingly held in San Diego, an entire session was devoted to Dr. Young's work. Six speakers discussed his contributions to the science of acoustics, including his impact on standards, his study of Space Shuttle sonic booms, and his half-century of acoustics consulting.[74] The first speaker related Dr. Young collaborated with Robert S. Gales in an acoustical consulting business. (Gales, incidentally, also served as ASA president.) In their "spare time," the two men worked regular eight-hour days at NEL, Gales as head of the Listening Division, and Young as the technical director's consultant on acoustics.

[74] Session 3aNS: "Noise, Architectural Acoustics, Animal Bioacoustics, Engineering Acoustics, Musical Acoustics, Physical Acoustics, Committee on Standard and Underwater Acoustics: Special Session to Honor the Contributions of Robert W. Young to Acoustics," 17 November 2004.

Undoubtedly the presentation that would have been music to Dr. Young's ears discussed his contributions to musical acoustics. During the 1995 interview, he mentioned he had been the second chairman of the Committee of Musical Acoustics, the first of ASA's technical committees. His scientific interest mirrored his instrumental interest: he played piano, violin, oboe, saxophone, flute, and piccolo. One of his early papers published in the society's *Journal,* which ultimately turned out to be his doctoral thesis, was on "standing waves in the flute."

Dr. William C. Cummings, a whale researcher for the Naval Information Warfare Center-predecessor Naval Undersea Center and later chief curator of San Diego's Natural History Museum,[75] spoke on Young's work in underwater acoustics and animal bioacoustics:

> All contemporary acoustics manuscripts from the Naval [sic] Electronics Laboratory (NEL), later Naval Ocean Systems Center (NOSC), had to pass his scrutiny. The wise chose to seek early comment from Bob Young or chance the possibility of endless editorial notations or internal memos...[76]

Cummings cited his "rare privilege of being so close to such authority, propriety and exactitude." He also made him human by recalling that many of his coworkers called him, ostensibly with affection, "Uncle Fussy Ears."

Los Angeles *Times* June 22, 1960, Page 1: "New Weapon Tested for Defense Against Subs/Rocket Homing Torpedo Combination Seen as Possible 'Equalizer' for Surface Ships," by Marvin Miles, *Times* Space-Aviation Editor "A new hard-hitting, Southern California weapon system combining rocket boost with homing torpedoes or atomic depth charges at last will give Navy combat ships a much-needed equalizing punch in anti-submarine warfare."

The cited *Times* article reflects an important aspect of the Navy R&D process: cooperative efforts of government employees and contract personnel. From the writer's standpoint, the importance was the business accruing to area companies.

As discussed in some detail in Chapter 7, the Anti-Submarine Rocket

---

[75] Naval Ocean Systems Center *Outlook*, August 12, 1977.

[76] William C. Cummings, "Bob Young and his contributions to animal bioacoustics and underwater acoustics," abstract, *Journal of the Acoustical Society of America,* Vol. 116, No. 4, Pt. 2, October 2004, 2665.

development at the Naval Ordnance Test Station resulted from serendipitous attendance at several planning meetings and a long weekend's effort to develop an alternative approach to that of the assigned Navy developer. Substantial time, funding, and expertise of NOTS personnel at both Pasadena and China Lake provided the basis for design of an appropriate weapon, its fire control system, and its shipboard launcher (which the article characterized as a "pepperbox").

At various points in its development, the NOTS ASROC effort required contractors to supply basic materials for early models and ultimately to manufacture production models. The *Times* article explained the project "… was initiated at the Pasadena annex of the Naval Ordnance Test Station (China Lake) which, as technical director, was joined by Minneapolis Honeywell Regulator Co. as prime contractor following an industry competition."

It continued with credit to the key personnel, citing first "Doug Wilcox, NOTS Pasadena civilian technical director…".

During the event the article described, invited news media viewed firing of "dummy torpedoes" from the Navy's first destroyer-leader USS *Norfolk* (DL-1) in the Straits of Florida between Key West and Cuba. USS *Skate* (SSN-578), which as noted in Chapter 6 was the first submarine to surface at the North Pole with substantial assistance from NEL personnel, served as the "target" for the rockets developed by NOTS.

ASROC was developed to provide a significant increase in the range at which a surface ship could counter a submarine. Up to this point, a destroyer involved in escorting a capital ship or a convoy could fling a depth charge only about 950 yards, or, if the circumstances dictated, charge the submarine's position at flank speed.

The *Times* reporter wrote,

> The advent of the atomic submarine nullified even these feeble defenses, however, inasmuch as the sub's speed and maneuverability scoffed at the almost hopeless efforts of surface ships to defense themselves. ASROC will change all of this—make the duel even, so to speak—for now a ship can hurl an acoustic torpedo or a nuclear depth bomb to the far perimeter of nominal submarine attack range.

A NOTS-developed Anti-Submarine Rocket is launched from USS *Higbee* (DD-806).

"A new and powerful anti-submarine weapon known as ASROC joined the fleet," noted the *Rocketeer* newspaper on January 13, 1961, in a retrospective article on station accomplishments:

> The front half of the missile is a torpedo and the rear a solid propellant rocket. When fired, the rocket booster falls off and a parachute lowers the torpedo into the water. Guided by an acoustical homing device, it closes on its target at high speed.

The demonstration rockets were fired at ranges from 2,000 to 6,000 yards from *Skate*, but for obvious safety reasons the torpedoes on the business end of the ASROCs were not armed or programmed to begin searching for a target. During the ensuing several years, the new weapon was installed on 150 Navy ships.

New York *Times*, August 26, 1960, Page 1: "Batter's Up at the North Pole with First Base 12 Hours Away" "The commander said the polar baseball diamond was laid out in such a way that a home run would travel 'from today into tomorrow and from one side of the world to the other,' and that a runner leaving the plate would arrive at first base 'twelve hours later.'"

Chapter 6 discussed the Center's arctic lab and its efforts to provide the U.S. Navy the capability to operate submarines in the Arctic. It is not the intention here to repeat that coverage. It would not be reasonable however, to report the impressive achievements of SSC Pacific predecessor laboratories in 1960 without mentioning voyages of USS *Sargo* (SSN-583) and USS *Seadragon* (SSN-584).

In the early morning hours of August 21, 1960, Commander George P. Steele II, commanding the nuclear attack submarine USS *Seadragon*, ordered his crew to surface the boat. On the surface, he radioed Commander, Submarine Force, U.S. Pacific Fleet, and reported for duty. He also announced completion of the first transit of the legendary Northwest Passage, while submerged.[77]

Seadragon, constructed at Portsmouth Naval Shipyard in Maine, had followed up its Caribbean shakedown with an unusual first operational cruise: rather than sailing *between* the Americas through the Panama Canal enroute to her assigned home port at Pearl Harbor, she had sailed *north* of North America and through the Parry Channel (with Commander Steele consulting Sir William Edward Parry's actual journal from his 1819 attempt to sail the passage). After the report to COMSUBPAC, *Seadragon* steamed on and surfaced at the North Pole, the third submarine to do so. Her crew played a softball game on the ice, with numerous topical jokes about a home run requiring the batter to run through all twenty-four time zones and Commander Steele hitting a fly ball at 4:00 p.m. on Wednesday that was caught at 4:00 a.m. on Thursday. The sub arrived in Hawaii on September 14, where a Navy Unit Commendation awaited crew members and NEL scientists Dr. Waldo Lyon and Art Roshon, who had supported operation of the sub's under-ice sonar and navigation during the sometimes-torturous voyage.

They'd missed a flurry of international headlines and stories about their feat, which, lacking a first-person narrative, tended to be general and thus missed the substantial interest the sub's CO had in up-close-and-personal views of astounding icebergs, one of which had a draft of 514 feet. Another, at 74 feet above the water

[77] William M. Leary, *Under Ice*. (College Station, Texas: Texas A&M University Press, 1999), 197-8.

and 108 feet below it and an underwater axis of 822 feet, was estimated to have a total mass of 600,000 tons.[78]

NEL *Calendar*, 4 November 1960: "Arthur Roshon To Receive Navy Department's Distinguished Civilian Service Award"

On the date of the *Calendar* publication reporting on the event, a substantial crowd gathered in NEL's Building 33 auditorium to witness the presentation of the Navy's most prestigious honor for non-military personnel, the Distinguished Civilian Service Award, to Art Roshon. As discussed in Chapter 6, Roshon had been one of the two NEL scientists aboard USS *Sargo* during its dead-of-winter cruise in February 1960 to demonstrate the feasibility of Arctic submarine operations regardless of season. A catastrophic loss of equipment critical to safe navigation left *Sargo*'s commanding officer with two alternatives, neither of them favorable to him and his crew. That's when Roshon suggested a third option, jury-rigging a hydrophone assembly to report iceberg detection signals. His "extremely imaginative" engineering, according to the CO, allowed the sub to continue its planned cruise of the Arctic and resulted in Roshon's nomination for, and eventual receipt of, the Navy's highest civilian award.

August 27, 1960, San Diego *Union*: "Electronic 'Brain' Bared By NEL For Combat Use" by Bryant Evans

An earlier chapter addressed the Naval Tactical Data System in some detail. Given that coverage, there is no need to repeat it, but the importance of this system to the Navy laboratory on Point Loma bears some mention.

The Navy Radio and Sound Laboratory emerged at the end of World War II as a relatively small laboratory. The transformation into the Navy Electronics Laboratory increased its numbers somewhat, as former University of California employees transferred with their projects into NEL, but the lab remained small, focusing a numerous basic research efforts that employed a single scientist or at most a small group. Continued growth required, among other considerations, opportunities for large groups of engineers and technicians to collaborate. (The Navy lab in the desert, NOTS, had such opportunities with several projects

[78] Arthur Roshon, "CTFM Sonar," 1994. See also USS *Seadragon* patrol report, 117-8.

mentioned above—Polaris and ASROC.) Although the arctic submarine work garnered major headlines, it never involved large numbers of personnel.

NTDS clearly changed the work environment. As noted in the station newspaper article reporting on the project, "A complete recounting of those involved in some phase or other of this tremendously important undertaking would include hundreds of persons in the Laboratory."[79]

The San Diego *Union* article noted NTDS "can restrict that information [targets' positions and courses] to that which is necessary to the decisions the officer has to make and eliminate all else." This of course was one of the two concerns about information gathering and processing: not getting enough information and getting too much for a human being to handle. The ability of NTDS to manage information to benefit the user was invaluable.

As the article related,

> [Project manager C.S.] Manning said that the officer, after seeing the position of his own and enemy crafts on the electronic display could then propose tactical solutions to the computer and it would tell him whether or not they were feasible in a matter of thousandths of a second. A man, he said, could do the same thing with a slide rule, but it would take him a couple of lifetimes.

Manning told the reporter transistors made the size difference; using vacuum tubes, "the device would have been more than 100 times as large."

In addition to the *Union* and *Calendar* coverage, the prestigious U.S. Naval Institute *Proceedings* included several articles at the time. One noted NTDS "aroused little interest among naval officers generally," but suggested optimistically those with concern "can educate themselves to prepare the Navy as a whole for the advent of electronic computers in tactical data systems…"[80]

Two years later, a former NEL operations officer wrote a more in-depth piece.[81] Obviously trying to reassure the skeptics, he stated, "… for NTDS is intended to aid the commander in reaching combat decisions, not to make them for him." He provided an excellent tutorial on what a general-purpose, stored-program digital computer was and how it worked, and was calmly reassuring:

---

[79] "NEL-Developed Naval Tactical Data System Revealed to the Public," NEL *Calendar*, 2 September 1960, 2.
[80] Captain Paul Van Leunen, "Naval Tactical Data System," October 1959, 128-9.
[81] Lieutenant Commander John A. Chastain, U.S. Navy, "The Role of Computers in Combat Control," USNI *Proceedings*, September 1961, 59-65.

> By using the speed and accuracy of the computer for those repetitious and error-prone manual operations that now assemble tactical data for evaluation and decision, the NTDS gives promise that the naval commander will at last have a means of employing his weapons with optimum effect in the face of the wide-ranging and fast-paced action of today's combat.

His reassurance was reasonable, as noted in a later Center command history:

> Beginning in 1955, NEL was the lead laboratory for the Naval Tactical Data System (NTDS), which became operational in 1961. NTDS remains (with updates) the standard Navy shipboard C2 system… Today, the Advanced Combat Direction System (ACDS), the Tactical Flag Command Center (TFCC), and the TADIL-J… projects are direct outgrowths of that work, which secured for NOSC its status as Navy lead laboratory for C2.[82]

April 11, 2003, Washington *Post*: "Navy's dolphin program rises to the surface/Goal is to find underwater mines"

There were no major national headlines when the Navy Marine Mammal Program began in 1960. At the time it was merely one of many novel ideas proposed by Naval Ordnance Test Station Technical Director Dr. William B. McLean that he thought might benefit the Navy someday. There were a few local headlines (L.A. *Times* and Ventura *Star-Free Press*) relative to a pool being constructed at the Naval Missile Center in Point Mugu for the training of porpoises, but that was about it. And there were no headlines when the program became operational and did provide those benefits McLean envisioned, due to strict security classification. It was, however, a story begging to be reported.

Although the Navy's Marine Mammal Program had its share of classification requirements that limited release of information, its popular interest was such it probably garnered more press headlines than all other Center projects *combined*. An unfair example: In 2003, the all-time record was set for news media queries to the Point Loma Navy laboratory: 613. Of those, 463 related to marine mammals. The headline at the opening of this section resulted from one of seventy-four queries that came in on a single day—March 25—and one of 300 for the week.[83]

The stimulus for that bonanza of news coverage was the statement by an

---

[82] Naval Ocean Systems Center Command History, Calendar Years 1985 and 1986, January 1987, 26.

[83] Tom LaPuzza, Public Affairs Officer for the lab when it was NOSC, NRaD, and SSC San Diego, maintained a detailed log of media queries during that period (1988-2006). Those records enumerate slightly more than 4,300 queries; 2,350 of them related to marine mammals.

official of the U.S. Fifth Fleet, several days before the agreed-upon date, that Navy dolphins were in the harbor of Umm Qasr, Iraq, hunting for mines as Operation Iraqi Freedom began. A media frenzy ensued. Navy planning documents had been in place for several weeks in anticipation, and although reporters, based on the volume of calls, had to wait for hours (and some overnight) for a personal phone interview, records show only one reporter was not contacted after he called.

As noted above, what has been known for decades as the Navy Marine Mammal Program began in 1960 with a low-key effort suggested by Dr. McLean, whose numerous ruminations covered a wide variety of technology areas. In this case, he suggested study of dolphins because their natural environment was of essential interest to the organization he served: the U.S. Navy.

Bill Powell, one of the beneficiaries of McLean's genius for spotting leadership qualities in unlikely places and the one who would mold the "low-key effort" into a viable Navy program, remembered:

> McLean read a book about dolphins, thought… 'I wonder if there's anything there we could learn from them,' and said, 'Let's let people do this if they want.'… and we had three or four scientists at China Lake who were dabbling with dolphins, trying to figure out things like: How do they swim? How fast do they swim? That was Tom Lang, hydrodynamicist.[84]

Lang, who graduated from the California Institute of Technology at age nineteen, moved a few miles east to the NOTS Pasadena facility, where he worked in hydrodynamic research. In less than a decade, he was "considered UOD's [Underwater Ordnance Department] top authority in the fields of aerodynamics and hydrodynamic research."[85] Although he was cited in several station newspaper articles for his off-duty development with his father of hydrofoils,[86] which would lead to his most significant contribution to Navy technology several decades later, his day-to-day work in the early years involved torpedo propulsion.

With McLean's interest in marine mammals and the NOTS acquisition in 1960 of a Pacific white-sided dolphin (*Lagenorhyncus obliquidens*) named

---

[84] Bill Powell, SSC Pacific oral history interview by Tom LaPuzza, September 13, 2012, 9-10.

[85] "Young Men Carve Successful Federal Service Careers," Naval Ordnance Test Station *Rocketeer*, October 3, 1958, 3. The article noted he also had a B.S. degree in civil engineering from Caltech and an M.S. in mechanical engineering from the University of Southern California. He was identified as an aeronautical research engineer (hydrodynamics).

[86] NOTS *Rocketeer*, November 16, 1956 and April 1, 1960.

Notty,[87] Lang was transferred (organizationally) from the Underwater Ordnance Department in Pasadena to the Research Department, mainly located at China Lake. He headed the Oceanic Research Group in a new division of the same name that pursued subjects near and dear to McLean's heart—marine mammals and undersea vehicles.[88] Lang was tasked with managing the marine mammal portion.

With no facilities of their own, NOTS scientists maintained Notty at a commercial oceanarium called Marineland of the Pacific on the Palos Verdes peninsula in southwest Los Angeles. Stories of remarkable swimming speeds inconsistent with dolphin muscle mass had suggested some undiscovered capability of drag reduction, possibly some sort of physiological thermal mechanism allowing the animal to do boundary layer control (the "boundary layer" being essentially the animal's skin). To provide a rigorous and accurate test, a contractor's towing tank in San Diego was used to measure the swimming speed of Notty and several later dolphin acquisitions. In the long term, the results were disappointing, recording fairly predictable speeds for a heavily muscled animal of the sea, but that would take some time to determine.[89]

Bill McLean's greater hopes for the mammals were based on the possibility of inter-species communication with humans. Experiments in that area with promising results, coupled with the early hydrodynamics testing and widening experience the animals were cooperative and easily trained, led to establishment of a formal "Dolphin Research Program" under Tom Lang in early 1962. Objectives included communication, hydrodynamics, and man-animal teaming.[90]

---

[87] "'Notty' Prepares for Role To Aid NOTS Scientists In Study of Sea Animal Locomotion, Hydrodynamics," NOTS *Rocketeer*, February 19, 1960, 3.

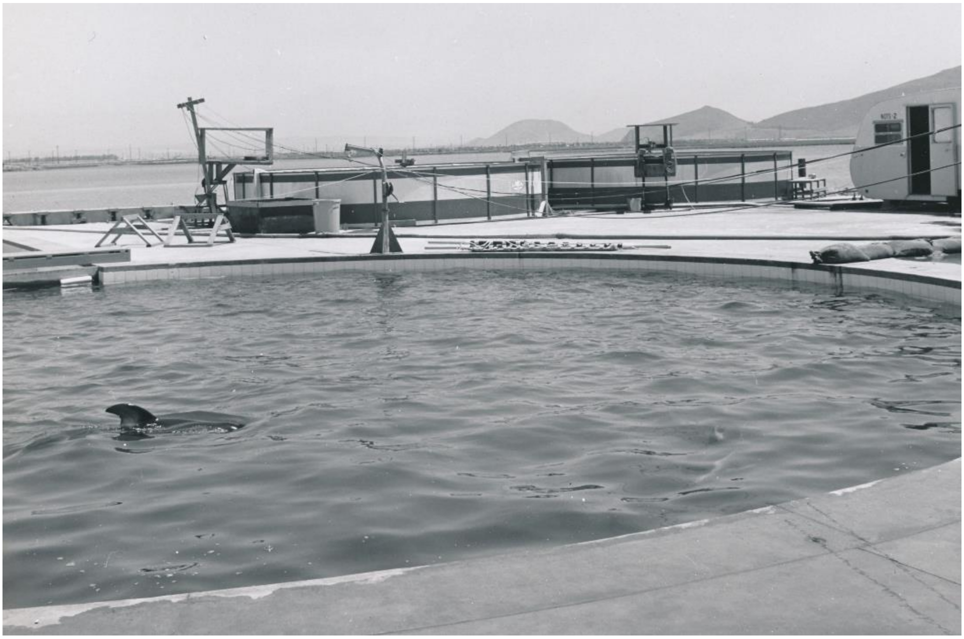
[88] NOTS *Rocketeer*, March 19, 1965. The new division was formed when McLean hired a septuagenarian, Dr. Rene Engel, with degrees from the Sorbonne and Caltech. Despite his age, Engel energetically launched the division, studying a variety of oceanographic disciplines. He is credited in the cited article as the first NOTS scientist to initiate formal scientific study of marine mammals.

[89] Thomas G. Lang and Dorothy A. Daybell, "Porpoise Performance Tests in a Sea-Water Tank," NOTS TP 3063, January 1963.

[90] *The Station Comes of Age*, 478. In a Lang in-house memorandum (Reg. No. P5006-116, 22 January 1964), providing essentially an annual report for 1963 on the effort, he cites himself as "NOTS Cetacean Research Project Director." Memo subject line is "NOTS/NMC Cetacean Research Program."

Point Mugu program

NOTS faced a serious environmental challenge to achieving those objectives: the Mojave Desert. The same vast emptiness of heat and sand that encouraged ordnance testing essentially prohibited on-site maintenance of sea mammals. The NOTS Pasadena Annex was closer but still 25-30 miles from the ocean, thus requiring initial work with marine mammals at Marineland and in the towing tank. Seeking a better solution, NOTS reached out to a sister Navy command with which it shared a much more fundamental mission: weapons testing.



The Marine Mammal Program, which despite rigid security requirements would be the most publicized program in Center history, began in a small pool at Point Mugu with a single "porpoise."

Shortly after the end of World War II, as the Navy made the determination to retain its ordnance testing facility in the desert, the service authorized another weapon testing facility on the Pacific coast: on October 1, 1946, the Secretary of the Navy established the Naval Air Missile Test Center at Point Mugu, California.

A decade later that organization was assigned as a subordinate command under the new Pacific Missile Range. On December 19, 1958, its name was formally changed to Naval Missile Center (NMC); it was assigned responsibility for

> conducting tests and evaluation of Naval guided missiles… for providing services and support to the Pacific Missile Range Headquarters; and for providing supporting services pertaining to the planning, development, evaluation and training in the fields of astronautics and bio-sciences.[91]

Consistent with the mission's "bio-sciences" portion, NMC agreed to team with NOTS to study marine mammals for potential Navy applications. In March 1962, the head of the NMC Life Sciences Department held a news conference on the site where construction had begun on a fifty-foot-diameter pool for porpoises.

It is an interesting anomaly that NOTS and NMC (and the reporting news media) consistently employed the term "porpoise" for the cetaceans the Navy had at those locations, even though the first were Pacific white-sided *dolphins*. As one technical reviewer of this work pointed out, "They are from different families of cetaceans." True statement. On the other hand, a review of the technical literature and *Rocketeer* articles reveals most NOTS scientists and news reporters used the term "porpoise" in their technical journal and newspaper articles. In an interview a half-century later, long-time Navy veterinarian Dr. Sam Ridgway advised:

> All of us tried to learn as much as possible from Woody [F.G. Wood] because, you know, he had a lot of experience, a whole lot more than us. I remember one episode where he's telling us the difference between dolphin and porpoise, you know, he went on and on, and then he finally said, 'Yeah, really there is no difference; they just called them porpoises.'[92]

After both Ridgway and Wood were transferred with their marine mammal charges to the undersea center in San Diego in the late 1960s, the latter wrote the definitive early history of the Navy's Marine Mammal Program, titled *Marine Mammals and Man: The Navy's* Porpoises *and Sea Lions*. [Emphasis added]

Over time, "dolphin" gradually became the preferred general term for the largest population of the Navy's marine mammals—*Tursiops*.

Several local papers reported on pool construction, and also the fact there were no marine mammals yet.[93] With construction completed several months later, a local fisherman was contracted to begin collection, and shortly afterward three Pacific white-sided dolphins called the pool home. Unfortunately, lack of basic

---

[91] *History of the U.S. Naval Missile Center*, Calendar Year 1962, 12.
[92] Sam Ridgway SSC Pacific oral history I interview by Tom LaPuzza, June 27, 2012, 18.
[93] "Navy Building Pool to Train Porpoises," Los Angeles *Times*, March 14, 1962, 16.

information on physiology and animal care resulted in their deaths fairly quickly. A fortuitous coincidence with the demise of the third, however, would have a far-reaching, positive effect on Navy work with marine mammals for half a century and more.

Sam Ridgway

In December 1960, a U.S. Air Force veterinarian, Sam Ridgway, was assigned to duty at the Oxnard Air Force Base, with responsibilities as well at NMC Point Mugu and the Navy Construction Battalion base at Port Hueneme. His normal tasks related to food inspection, caring for sentry dogs, and conducting clinics for pets of base personnel. Point Mugu also had a small menagerie of research animals requiring attention. In the summer of 1962, one of the naval officers assigned to that unit requested Ridgway perform a post-mortem exam of the last NMC dolphin to die.[94] The veterinarian had heard about the dolphins, but had not been asked to care for them and in fact had never seen them.

When the examination was complete, Ridgway presented a report to a small group of Point Mugu personnel. The Navy officer was impressed enough that he shared information on a potential arrangement for NMC to provide physical facilities, some training capabilities, and, he hoped, Dr. Ridgway's veterinary care in support of the NOTS marine mammal research program. Ridgway's service obligation ended in the fall; the Navy officer requested the Air Force assign him additional duty in caring for any marine mammals acquired in the meantime.

At the time, NMC had two Navy enlisted technical device technicians—Bill Scronce and Marty Conboy—who supported training of Navy pilots for high-altitude flying. They became substantially interested in the mammals, regularly spending off-duty hours working with them. Obviously unanticipated then, they would play a substantial role for decades in the Navy's work with the animals.

As reported in the NOTS *Rocketeer* several years later,[95] Sam Ridgway, his Air Force duty concluded, had settled in as the Navy civilian veterinarian. Scronce and Conboy were assigned to the project. NMC constructed a new piping system

---

[94] Sam Ridgway oral history I, 5.

[95] "NOTS and Point Mugu Scientists Join in Study of Porpoises." NOTS *Rocketeer,* March 19, 1965, 4-5.

(funded by NOTS) to supply ocean water to the pool, based on Ridgway's belief flaws in the original system had contributed to the deaths of the first dolphins.

The first and most obvious requirement was to procure new animals. In September 1962, an NMC aircraft was dispatched to the East Coast to pick up and transport five dolphins. The animals had been captured off Gulfport, Mississippi, on behalf of Pacific Ocean Park (POP), a theme park established on the Santa Monica pier in 1958. Among its attractions was an oceanarium similar to Marineland of the Pacific, with performing marine mammals. The animals in Mississippi were awaiting transport to California, for which POP had no funds. In return for the Navy's transport, it received two of the dolphins, one of which died at POP awaiting completion of the water system. The other was the first dolphin transferred to Point Mugu with system completion in the spring of 1963.

Earlier in the year, another oceanarium, Marineland of Florida, had offered the Navy three animals. Ridgway and the training device techs, Conboy and Scronce, traveled to Marineland to bring the animals back, but also to meet its curator, F.G. Wood, who was being recruited to manage the nascent NMC marine mammal effort. Thus, by the spring of 1963, the Navy had four dolphins at Point Mugu to resume research. In June, Forrest Wood arrived as facility manager.

In addition to Tom Lang's hydrodynamic work, there were several other subjects under investigation: Ralph Penner, hired from Marineland of the Pacific as one of the first trainers, was working on translating "unintelligible" dolphin vocalizations into something humans might understand; UCLA graduate Bob Bailey was "seeking remote acoustic control over porpoises"; [96] and UCLA graduate student William E. Evans contributed a sea lion to the inventory. Evans had worked for a commercial company conducting early research of marine mammals. In a study of Roxie, he demonstrated sea lions didn't need echolocation since they had excellent low-light-level vision and good underwater directional hearing (substantially important findings that would benefit the Navy program). After the company moved on and no longer required a sea lion, Evans kept it in his backyard. When he began graduate studies at UCLA, he donated the sea lion to the NMC facility. After his studies, Evans would be an important researcher for the Navy's mammal program for thirteen years, would chair the Marine Mammal Commission, and later would serve as Undersecretary of Commerce. [97]

---

[96] NOTS *Rocketeer*, March 19, 1965, 4.
[97] See: *Aquatic Mammals* 2010, 36 (4), 413.

Nuclear physicist becomes dolphin audiologist

Perhaps most important to the fledgling effort was another remarkable McLean discovery, who would push the boundary of dolphin research: Dr. C. Scott Johnson was a nuclear physicist who as a post-doctoral fellow at the University of Chicago's Enrico Fermi Institute studied elementary particles called muons. According to Sam Ridgway, McLean met him at a conference and invited him to join his staff:[98] "I guess Dr. McLean thought that somebody that could do particle physics maybe could do science with dolphins," Ridgway suggested.

Upon arrival at Point Mugu, Johnson advised he planned to study dolphin hearing, seeking details of their audiogram—their hearing threshold at various frequencies. Provided a dolphin named Salty for his study, "he very meticulously looked into what kind of set-up he needed to test the hearing," concluding plastic pools were not satisfactory and so building a thirty-foot-diameter tank of more acoustically favorable redwood.

"Scott was very particular about everything he did," Ridgway offered. "He made all his own equipment; he didn't trust anybody else to supply the equipment that he was going to use. He tested everything out thoroughly."

In his own efforts to develop baselines for animal husbandry, Ridgway came monthly to take blood samples, which Johnson complained interrupted his training and data collection. He found an effective means of limiting the interruptions:

> So about the third month I came over and he had Salty lift his tail onto the side of the pool, and Scott held the dolphin's tail and said, 'Now take the blood sample.'… So that was the first time that I know of that anybody thought about having the animal cooperate in its own medical care... A nuclear physicist came up with the best husbandry method we had.[99]

Johnson's training of marine mammals to participate voluntarily in their own medical procedures is a practice continuing to the present (2020). Over the years, those husbandry procedures materially assisted trainers and veterinarians in providing outstanding health care to their charges, resulting in behavior-based awards from the International Marine Animal Trainers Association.[100]

---

[98] Dr. Sam Ridgway SSC Pacific oral history II interview by Tom LaPuzza, August 8, 2012, 22-26.

[99] Ridgway interview II, 25.

[100] See Naval Ocean Systems Center *Outlook*, February 15, 1991, 3.

More significant for basic scientific research, Johnson published his audiogram, which Ridgway related is "still cited today. He published this curve on their hearing capability at different frequencies. He was the first one to look at their really low-frequency hearing…"[101]

Scott Johnson would transfer to San Diego in 1967 and remain until his retirement in 1992, researching beluga whale hearing and evaluating early attempts at bionic sonar, efforts to replicate marine mammal sonar in mechanical systems. He also would become an international shark expert, among other things inventing a "Shark Screen" passive protection device for downed fliers and shipwrecked sailors. He also would be one of the few Defense Department civilians to earn the Military Humanitarian Service Medal.[102]

Ridgway himself, hired for his veterinary skills, necessarily had to increase those skills substantially since his patients were no longer dogs and cats, and the literature relating to marine mammal medicine was sparse. In 1963, he teamed with the Pacific Ocean Park veterinarian to publish a paper on their experiences with marine mammals.[103] It was the first of hundreds of his papers over the next half century on marine mammal anatomy, behavior, training, and medical care.[104]

One of the critical requirements for Ridgway was establishing "norms" for his patients. To that end, he started gathering data

> from Day One, really. For our original records we took a picture of every animal and we had a little manila folder and where it came from and the initial blood results… During the whole transport [from Marineland of Florida in 1963], I was taking their temperature, taking their respiration rates, checking heart rhythm and things like that.[105]

Ridgway, his interest increasing in research; studied diving physiology. In that endeavor he had a partner; their work together would gain them substantial fame.

---

[101] Johnson, C.S., 1966. "Auditory Thresholds of the Bottlenosed Porpoise (Tursiops truncatus Montagu)," U.S. Naval Ordnance Test Station Report T.P. 4178.

[102] See Naval Undersea Warfare Center *Seascope*, February 28, 1969, for details on the shark screen, and Naval Ocean Systems Center *Outlook*, June 20, 1980, for his assistance to Navy special forces personnel in clean-up of radiation ravaged Eniwetok Atoll.

[103] Miller, R.M. and S.H. Ridgway, 1963. "Clinical experiences with dolphins and whales," *Small Animal Clinician*, 3: (4), 189 193.

[104] See a listing at http://www.researchgate.net/profile/Sam_Ridgway/publications accessed May 13, 2020.

[105] Ridgway interview II, 34-35.

Tuf Guy

When the September 1962 NMC transport from the East Coast arrived at Point Mugu, one of the five Atlantic bottlenose dolphins aboard was so aggressive and caused so many bumps and bruises to the handlers he was named Tuf Guy.[106] Ridgway made certain it wasn't one of the two selected as compensation for flying POP's other three animals to Los Angeles. Shortly thereafter, the oceanarium fell on hard times, and in the process of going out of business offered a much subdued, ill, and emaciated Tuf Guy to the Navy for $150.[107] Forrest Wood agreed to purchase the animal for Ridgway's research, suggesting if the dolphin lived they should change the name to Tuffy.

Nursing the critically ill animal back to health over an extended period provided substantial satisfaction for Dr. Ridgway the veterinarian, but the animal's revitalized aggressiveness was less so for Dr. Ridgway the researcher. Luckily, a student intern he had hired for the summer, Debbie Duffield, was convinced she could tame the wildness, and in the few months before she returned to her classes she had done so. The researcher had the animal needed for his experiments.

While open-ocean training was underway, including diving on command, one of those great-opportunity events occurred: SEALAB.

The Navy's Man-in-the-Sea program originated with a small habitat, SEALAB I, placed on the sea floor in 193 feet of water at the Argus Island research tower southwest of Bermuda. (In the interests of strict accuracy, the program began with Project Genesis, the first studies of saturation diving by Captain George F. Bond, MC, USN when he was assigned to the Naval Medical Research Laboratory.[108]) SEALAB I was the first actual effort with humans "living" in the sea. The intent was to determine the effects on humans of remaining underwater, and thus under pressure, for extended periods, and specifically to develop "the technology and equipment necessary to allow man to live and work in the ocean depths." (The project title was variously SEALAB, Sea Lab, and Sealab. The all-caps version is the one employed in official documentation, so we will use it.)

---

[106] Dr. Sam Ridgway, *The Dolphin Doctor* (Robbinsdale, Minnesota: Fawcett Publishers, October 31, 1988), 38.
[107] Ridgway interview I, 9.
[108] See "U.S. Navy Man in the Sea Program Fact Sheet," 15 February 1968.

SEALAB II was scheduled for the summer of 1965, "locally" for the group at NMC Point Mugu: it was sited off the Scripps Institution of Oceanography pier in La Jolla, about a hundred miles to the south. Forrest Wood arranged with SEALAB officials for Tuffy to participate. Ridgway and his trainers had six weeks to work with the dolphin, preparing for a role that was part show biz and part scientific data collection. The "show biz" was that Tuffy was the "mailman," delivering waterproof packets of official U.S. mail and also tools to the aquanauts living in the SEALAB habitat. The serious parts dealt with Tuffy's ability to work with divers, his ease in diving two hundred feet underwater with none of the precautions required for humans, and his training to find "lost" divers, whose separation from the habitat in a real-life situation would mean almost certain death.

Dr. Sam Ridgway worked with whales during much of his career. In the left photo, Sam (on right) preps one for transport at Point Mugu. Almost three decades later, he performed substantial research on the Navy's belugas (white whales) in San Diego.

Tuffy and his human teammates spent a week at SEALAB, to wide acclaim and substantial publicity for the experiment itself and for Navy use of marine mammals.[109] On the last day, Captain George Bond, the project medical officer, stopped by to chat. He'd just heard news about Viet Cong swimmer-sappers

---

[109] F. G. Wood and S. H. Ridgway, 1967, "Utilization of Porpoises in the Man In The Sea Program." In: *An Experimental 45-Day Undersea Saturation Dive at 205 Feet*. ONR Report ACR-124, 407-411.

blowing up a large barge and repeated attacks on ammunition ships in Vietnam. He wondered aloud if Tuffy could be trained to do something about those attacks.

Returning to Point Mugu, Ridgway and trainer Wally Ross began efforts to see if a dolphin could detect swimmers and divers and report that information. The diver-detection concept also prompted interest in finding "stuff." As reported above and earlier in Chapter 7, NOTS had introduced the Anti-Submarine Rocket (ASROC) into the fleet in 1961, and was required to continue testing for weapon

Former Navy diver Bill Scronce was significantly involved in the mammal program for decades. He worked early with Tuffy.

verification and upgrades. Occasionally an unarmed nuclear version had to be tested; proper operation required it to sink to a depth of 180 feet before detonation. After one such test, with an acoustic pinger attached, the inert rocket was on the bottom 200 feet deep. Tuffy was dispatched to attach a recovery line. (Ultimately ASROC Quality Assurance round recovery would be handled by California sea lions. The first recovery, however, was performed by Tuffy.)

Ridgway, meanwhile, had not given up on his desire to research Tuffy's diving-depth capabilities. Point Mugu photo and diving personnel responded to his request, fashioning a camera that could be lowered to a depth of 1,000 feet. Tuffy was trained at increasing depths to dive and flip a switch, resulting in activation of a strobe light and clicking the camera shutter. The photos confirmed Ridgway‘s theory that under pressure a dolphin's rib cage partially collapsed:

> The photographs showed that indeed his rib cage was greatly deformed by the hydrostatic pressure on his lungs… The pressure collapsed the tiny air cavities in the lung (the alveoli) and prevented nitrogen in the lung air from going into circulation, thus preventing the bends after these deep dives.[110]

Bill Powell and a lab in Hawaii

A spring 1965 *Rocketeer* two-page spread on the NOTS/NMC cetacean project included, as its very last sentence, a generic management statement: "Bill A. Powell… serves as NOTS Coordinator for all studies under NOTS sponsorship."[111] Powell, a junior employee in the Behavioral Sciences Group at China Lake, had been detailed a year earlier by his supervisor, whose direction came personally from McLean, to spend several weeks at Point Mugu to observe reported obstacles to facility peace and harmony between NOTS and NMC employees and to recommend solutions. He wrote up his findings and solutions, which he characterized as simply providing administrative support (clerical, mail, financial services), and appointing a NOTS manager at the same civil service grade as the NMC manager. His task finished, he went back to his normal duties. Until, that is, McLean's secretary called and asked him to accompany the technical director on a trip to Point Mugu. McLean read the report on the drive. They toured the facility and the technical director chatted with his handful of employees far from headquarters. During the drive back, he asked Powell to take the job managing the NOTS portion of the joint project.[112]

Powell coordinated the NOTS marine mammal work at Point Mugu for several years, beginning in 1964, but with reorganization rumors and McLean's interest in developing a scientific facility on an island somewhere, he volunteered to go to Hawaii and set up a laboratory there. That story is related in Chapter 11.

While Powell and his team were establishing that lab, their former associates

---

[110] *The Dolphin Doctor*, 154.

[111] NOTS *Rocketeer*, March 19, 1965, 5.

[112] See Bill Powell oral history interview, 11-13, for an amusing account of how McLean installed him in the "coordinator" role.

were continuing their marine mammal research at Point Mugu. As one consequence of the Navy's reorganization of its West Coast labs in 1967, both groups were transferred organizationally to the new Naval Undersea Warfare Center (NUWC). Sam Ridgway traveled to Cambridge University in the fall of 1970 to pursue his doctorate in marine mammal physiology on a Navy fellowship. While he was in England, the Point Mugu marine mammals and personnel were transferred to San Diego, where the Navy had moved NUWC headquarters. A new facility, the Marine Life Sciences Laboratory, was constructed for them on the Pacific Ocean side of Point Loma, near the U.S. Coast Guard lighthouse.

Although the new laboratory, dedicated in January 1972, had the acoustically superior redwood tanks for dolphin sonar research, there was no access to the Pacific, only a few tens of yards away, because the intervening tide pools, part of Cabrillo National Monument, were protected by federal law. That fact, and the sub-standard system for pumping seawater into the tanks, made it a scenic and secure facility that failed to meet important requirements. Fortunately, within a decade, a pier on the harbor side of Point Loma at the Center's headquarters became available, and the mammal operation moved there. The animals now resided in their natural environment, which in addition to improving the human-animal working relationship was also healthier for them, with the substantial tidal exchange in the bay.[113]

Those improvements would be significant in the development of the marine mammal operational system that was on hand in Umm Qasr and prompted that headline ("Navy dolphin program rises to the surface…").

This, then, has been a chapter recounting some impressive achievements of both Navy laboratories discussed in this history in a single year. From the absolute bottom of the sea to space, from peaceful scientific research to development of platform- and city-destroying weapons, from grunge-work at the soldering bench to leadership of an internationally respected scientific body, today's Naval Information Warfare Systems Center Pacific's founding organizations continued their substantial contribution to the capabilities of the U.S. Navy.

Frank Knemeyer, who played a major role in weapons development for many years, asserted that "the 1960s were the period of China Lake's maturity, the era 'when China Lake really came of age… We weren't afraid to tackle anything.'"[114]

---

[113] Ridgway interview II, 41-42.
[114] *The Station Comes of Age*, 658.

Slan

Sam Ridgway recalled that one of the early “accidental” births prior to the marine mammal breeding program was noteworthy: “One of our best females in the Mark 6 program came up pregnant. She had been in Vietnam and Guam and on various exercises. In early 1979, we had to take her out of the system because she was six months pregnant. She calved in June… Mom dolphin continued to work in the system, deployed to the Persian Gulf in ’87-’88 and elsewhere… Her calf has been an outstanding dolphin for us and will be 35 this summer. The accidental pregnancy was a great success.”[115]

Slan, a female Atlantic bottlenose dolphin (*Tursiops truncatus truncatus*), was collected in 1968 off the Florida Keys as one of the original “Short Time” swimmer defense dolphins; at the time she was about eight years old. Transported to Hawaii, she trained with four other dolphins and assigned Navy divers who would work with the animals during the deployment to Vietnam. She was named by her primary Center trainer, Don McSheehy, for a character in a novel who could read minds. Considered by some as “the most consistent and best overall Short Time dolphin,” she was also one of the most traveled, as she “logged well over 100,000 air miles.”[116]

In the midst of all that world travel, she was pulled out of active system work so she could deliver a calf (Slooper). After several years of nursing her calf, who in mimicking Mom actually learned rudimentary behaviors expected of Navy dolphins, the two were separated and Slan returned to swimmer defense system work. Slooper became one of the program’s best research dolphins. She also became one of its finest breeders, producing four calves, thus making Slan four times a grandmother. “On top of that,” according to Ridgway, “Slan re-lactated last year [1992] and raised an orphan dolphin.”[117]

[115] Ridgway interview II, 49-50.
[116] Sam Ridgway email to Tom LaPuzza, 10 December 1993.
[117] Ridgway email.

9

Decade of Change

Early chapters of this history described the destruction and fear generated by German U-boats at the outset of World War II, and the substantial efforts, many by the Navy laboratories discussed in these pages, to counter the threat of those undersea menaces. While those laboratories—teaming with the University of California and the Columbia University divisions of war research, California Institute of Technology, U.S. Tenth Fleet, and numerous other organizations and companies—combined to halt that threat, that wasn't the end of it.

Three years after World War II ended, despite the decimation of the German submarine fleet, a study conducted by Arleigh Burke identified anti-submarine warfare as a carrier task force's first mission.[1] This matched well with the mission of the Naval Ordnance Test Station's Pasadena Annex: "To plan and conduct a program of research and development in the field of underwater ordnance, including complete torpedo and missile weapons systems for the fleet."[2] As detailed in Chapters 7 and 8, the annex contributed significantly to the inventory of new, more effective anti-submarine weapons available to the fleet in the decade following the war. It had done so through the dedication, ingenuity, and hard work of its technical staff, in spite of woefully lacking facilities. Those shops were not designed for weapons development; upgrades were infrequent and expensive.

As the decade of the 1960s unfolded, the ASW threat not only continued, but strengthened, not in numbers but in technology, as the Soviet Union put to sea nuclear-powered subs. To keep pace, NOTS initiated, often only on paper, a series

---

[1] Arleigh Burke served numerous assignments as a destroyer division commander during World War II and the Korean War, and was selected over ninety-nine officers senior to him, including every three- and four-star admiral, to become Chief of Naval Operations in 1955. He was reappointed for two additional terms, but declined the offer of a fourth. His decision significant to this history was establishment of the Special Projects Office for Polaris development. A new class of guided missile destroyers, lead ship of which (DDG-51) was named in his honor, joined the fleet in the early 1990s.

[2] NOTS Station Journal 1959, Jan-June, 183, cited in: Cliff Lawson, *History of the Navy at China Lake, California, Volume 4: The Station Comes of Age (*China Lake, California: United States Navy, Naval Air Warfare Center Weapons Division, 2017), 413-14.

of actions to provide Pasadena facilities to pursue ASW responsibilities more vigorously, including one for co-location with the electronics lab in San Diego.

Studies proliferate

Plans for change and expansion in Pasadena and San Diego reflected higher-level change within the Navy and Defense departments during this period, particularly related to research and development facilities. Myriad reviews and studies were conducted in the several decades after World War II, with findings resulting in several, or many, recommendations for change in the DoD labs. Frequently the result of one major review was another study (or studies) to address issues uncovered in the first. As the chair of one of those studies quipped, "Probably no class of institution has been studied and analyzed, praised and criticized, organized and reorganized to the degree that has been the lot of the Defense laboratories."

The magnitude of the effort was so great, in fact, that it stimulated the Navy to commission what amounted to a study of studies.[3]

A major change in defense-related R&D occurred in 1958, when President Eisenhower advocated establishment of a new top-level position for the department. Concerned about lack of control in DoD, he insisted that

> we should reorganize Defense research and development to strengthen the Defense Secretary's control over it. To this end, I recommended the establishment of a new position of Director of Defense Research and Engineering… [He would] supervise all research and engineering activities in the Department and direct all research and development requiring centralized management. He would thus minimize duplication and rivalry among the three services in their work in science and engineering.[4]

(In the unlikely event they had been asked their opinion, leaders of the Navy's weapons lab at China Lake like Dr. William McLean and Robert Hillyer would

---

[3] Department of the Navy, *Review of Navy R&D Management 1946-1973*, June 1, 1976. A major contracted project resulting in a report of nearly 500 pages, it acknowledged in its Preface the "numerous case studies… on various projects and historical information," but also recognized lack of a "systematic attempt to review and document the circumstances surrounding significant developments." Its purpose was "to fill this gap."

[4] Dwight D. Eisenhower, *The White House Years. Waging Peace, 1956-1961* (Garden City, New York: Doubleday & Co., Inc., 1965), 248.

have made an emphatic, well-reasoned case for the *value* of competition and selected duplication in military R&D, and the negatives of high-level control.)

The Navy-contracted R&D management "study of studies" criticized the Eisenhower-generated DoD Reorganization Act as "demonstrably" enhancing the authority of the Secretary of Defense "at the expense of the three military departments." The perceived intent was to "eliminate unnecessary duplication in the Department of Defense, and particularly in the field of research and engineering by vesting its overall direction and control in the Secretary of Defense."[5]

Among the act's major actions was the upgrading of the Assistant Secretary of Defense for Research and Engineering to the number three ranking in DoD, with that new title of Director, Defense Research and Engineering (DDR&E).

First DDR&E

Eisenhower nominated Dr. Herbert York as the first DDR&E. York was at the time the first chief scientist of the newly created Advanced Research Projects Agency. Dr. Howard Wilcox, who succeeded Bill McLean as lead on Sidewinder development, headed two NOTS technical departments and served as assistant technical director, arrived from China Lake shortly to serve as York's deputy.[6]

Although he first tended to leave decision authority to the services, centralization became substantially important to York's organization in short order. Seeking to explain, one DDR&E executive said:

> There is no thing [sic] that would make our job easier and no thing that we would rather do than to leave the entire research and development job to the services. This, in point of fact, is exactly what we try to do. But we feel that there are many areas in which the services have abdicated their responsibilities. It's a matter, as we see it, of finding the best way to do the job.[7]

The first individuals serving as DDR&E between 1958 and 1973—York; Harold Brown, who would later be Secretary of Defense; and John S. Foster, Jr.—

[5] Review of Navy R&D Management, 53-54.
[6] Director of Navy Laboratories History Study interview of Dr. Howard A. Wilcox by A.B. Christman, March 15, 1978, 5.
[7] *Review of Navy R&D Management*, 56.

would in fact commission a large number of studies to determine the best way to do the job, and with results in hand proceed to implement recommended actions.

Bureau chiefs still in control

Eisenhower's recommendation to establish the new DDR&E reflected what the Navy had considered at the assistant secretary level several times, each time rejected for one reason or another (actually, almost always for the same reason). For more than a century, since the Navy's five initial material bureaus were established in 1842, the real authority for developing new technologies lay in the hands of the chiefs of those bureaus (Ships, Ordnance, etc.), the "platform barons," as they were often termed: "In 1946, the Navy appropriation structure reflected the bureau chiefs' firm hold on the department's R&D purse strings."[8]

Contact with congressional committees—attending hearings and testifying appropriately, presenting their financial requirements and justifying them—was almost exclusively the purview of the bureau chiefs. Those presentations to Congress differed substantially from one another, based on the preferences and personalities of the bureau heads. For example, a Bureau of Ships submission included an appropriation with a subhead of Project 9 titled "Investigation and Test." Its three activities included management of 133 research and development projects in, and operation of, the bureau's eight laboratories, among them the Navy Electronics Laboratory on Point Loma. On the other hand, for the Bureau of Ordnance there was a subhead titled "Proof, Tests and Experimental Work," comprising seven activities, mostly research. The Naval Ordnance Test Station was included in that bureau's funding request. This inconsistent presentation of research and development, often with misleading titles, meant "Congress effectively reviewed only fragments of the total [Navy] R&D program."[9]

Contributing to the power of the platform barons and additionally limiting the ability of Congress to exercise its legal watchdog function was "the bureau chief's broad authority to reprogram funds—virtually independent of any review—within the lump-sum appropriations designated for his bureau's program."[10]

---

[8] *Review of Navy R&D Management*, 259.
[9] *Review*, 261.
[10] *Review*, 262.

National Security Act signed

The early, and very preliminary, change to that arrangement had come with the National Security Act of 1947. During a few critical months in the summer, President Truman signed the act, creating the National Military Establishment (July 26), which replaced the more than 150-year-old War Department; the Senate confirmed James S. Forrestal as the first Secretary (September 17) heading that establishment; and the following day the establishment began operations. (It was renamed the Department of Defense August 10, 1949.) One important provision of that act was the authority/requirement of the newly appointed Secretary to oversee the budget determinations and requests to Congress of all the entities of the National Military Establishment, including the Department of the Navy.

Seeking to understand with greater clarity the substantially scattered research and development initiatives of the National Military Establishment/Department of Defense, Congress worked to establish a single R&D account for all those initiatives. By FY1952, it had succeeded in doing so for the Army and Air Force. On the other hand, "The Navy Department resisted the trend toward a Navy-wide R&D appropriation: more specifically, the still-strong bureaus resisted any erosion of their authority and control over research and development."[11]

With increasing pressure to fall in line, Secretary of the Navy Charles S. Thomas, following FY55 congressional budget hearings, assigned responsibility to the Chief of Naval Research to develop and submit the Navy's consolidated R&D budget to the responsible official (the assistant secretary for air).[12] A year later, he assigned the Office of Naval Research (ONR) responsibility for the new, consolidated "R&D, Navy" appropriation. The immediate result was an increase in the total funds for which ONR was responsible from $60 million to $340 million. Although the intent was for the office to function essentially as comptroller, the action did allow it actual influence over allocation decisions.

---

[11] *Review*, 271.

[12] The CNR at the time was Rawson Bennett, NEL commanding officer and director immediately after World War II. He continued his distinguished career, serving as CNR and in several senior positions at the Bureau of Ships. Even when he retired, he wasn't finished; he was recalled to active duty in 1962, and, as will be discussed later in this chapter, directed the R&D study for a major Navy management review.

Desire for fiscal accountability increases

The Defense Reorganization Act and the attendant creation of the position of Director, Defense Research and Engineering stimulated the Congress to intensify its efforts to understand, and thus establish some fiscal control over, the complex and expensive DoD research and development projects and processes. At the same time, the departments of Defense and Navy both made considerable efforts to simplify their many categories of appropriations requests. One joint proposal by the DoD comptroller and the Bureau of the Budget was establishment of "eight activity-oriented titles reflecting the way the Department as a whole managed its resources. Title V was to be designated 'Research, Development, Test and Evaluation.'"[13]

For more than a century, it had been the responsibility of Navy bureau chiefs to field new technology. Within that responsibility came authority to move funding, which they themselves had sought and gained from Congress, anywhere they desired, from one phase of development to another within the same program, or from one program to another. They could do so with little or no oversight.

Among other things, this allowed them to regulate development closely, determining, for example, whether to introduce new technology in a program already underway. Recognizing the potential effects such introduction would have on cost, schedule, and/or performance, the three measures critical to program success, bureau chiefs tended to be conservative, such that once a program was making its way through the various requirements headed for a ship or submarine or aircraft, there was little incentive to consider alternatives. If a new sonar, for example, was scheduled for deployment on destroyers and cruisers in six to nine months, why consider at that stage upgrading that sonar with new processors? In Volume II, we will discuss "disruptive technologies," but in the 1960s the notion of that adjective was enough to prompt disregarding such technologies entirely.

The Navy bureau chiefs opposed the DoD/Bureau of the Budget proposal for a variety of reasons, although the most obvious was the potential for limiting their discretionary power in allocating and reprogramming budgets and revising program schedules. Rear Admiral Rawson Bennett, in his role as Chief of Naval Research, stated very clearly the only possible reason for this proposal was "to put

---

[13] *Review*, 278.

complete control and direction of the R&D programs in the hands of the Director of Research and Engineering."[14] He claimed "this is contrary to the testimony of the Secretary of Defense and his staff when justifying the DoD Reorganization Bill before the committees of Congress." His memo claimed this proposal would not increase efficiency at all, but increase costs and time in formulating a budget. His conclusion: "The whole purpose for the shift in appropriation structure must be found in the desire to provide a centralized control of the funds for R&D…"

New top-level positions

Reacting quickly to the establishment of the new DDR&E position, the Navy added two top-level positions of its own in the offices of the Secretary of the Navy and the Chief of Naval Operations, creating a civilian assistant secretary for research and development and a new military deputy to the CNO. The new ASN, confirmed February 5, 1959, was Dr. James Wakelin, a Yale Ph.D. in physics who earlier had been involved actively in the creation of the Office of Naval Research.

The Assistant CNO for Research and Development, Rear Admiral John T. Hayward, was selected as the first Deputy CNO for Development a few months later, on April 28. Hayward appeared initially in this history in Chapter 4, when he was serving as the first "Experimental Officer" at NOTS China Lake. Although as a naval aviator he was a subordinate of Commanding Officer Captain Sherman Burroughs, in actuality in his position he worked directly for California Institute of Technology leader Dr. Charles Lauritsen and for Dr. William Fowler. Assigned to NOTS as a Navy commander, Hayward had advanced in rank to rear admiral as Assistant CNO for R&D, and in his position as Deputy CNO was promoted to vice admiral. He later served as president of the Naval War College. All pretty impressive credentials for a boy who dropped out of high school at sixteen and lied about his age so he could join the Navy as an enlisted sailor.

---

[14] Memorandum, Chief of Naval Research to NAVCOMPT, Subject: Comments on Proposed Revision of Defense Appropriation Structure, October 16, 1958.

Vice Admiral John T. Hayward

By virtue of establishment of the positions initially, and by the accomplishments of Dr. York, Dr. Wakelin, and Vice Admiral Hayward in them,

> The creation of the offices of the Director, Defense Research and Engineering, Assistant Secretary of the Navy (Research and Development), and Deputy Chief of Naval Operations (Development), set the stage for revolutionary changes in the way research and development programs were to be planned and justified during the following decade.[15]

Despite the significant objections of the bureau chiefs and the CNR, Hayward, while still Assistant CNO for R&D, had advised his superior the new budget plan proposed by the DoD comptroller and the Bureau of the Budget would be advantageous to the Navy, saying, "R&D in the Navy should receive a tremendous impetus… Several echelons of budgetary reviews that plague the Navy R&D program will be eliminated."[16] He followed up in the very next sentence, however: "The Material Bureaus will initially resist the full and complete application of this new procedure. Past procedures and habits are too long engrained – they will fear for their prerogatives and the too close scrutiny of the CNO in their development and production programs."

---

[15] *Review*, 207.
[16] Memorandum, ACNO (R&D) via VCNO, Subject: Recommended Action Concerning Navy Policy for New Research, Development, Test, and Evaluation (RDT&E) Appropriations F760 (Confidential), December 9, 1958.

But, he concluded,

> Finally the overall Navy R&D program should be aided greatly in achieving the ultimate goal of producing acceptable service hardware designs of new and improved weapon systems and weapon system components in time to add to the Navy's combat readiness – not too little nor too late.

Hayward and his boss, however, were powerless to do anything to force the point. If the issue had been a strictly "military" one, for example deployment of a carrier battle group, the Chief of Naval Operations would have directed the appropriate officers and they would have carried out his orders immediately. In the case of the "material bureaus," however, there was a problem: the officers who headed those bureaus, all of them with fewer stars than the CNO's four, did not report to him. As will be discussed shortly, the Navy had established a bilinear structure decades earlier, which required those bureau chiefs to report not to a military officer but to the civilian Secretary of the Navy. The circumstances leading to establishment of the new Navy ASN and Deputy CNO positions, however, would change that in the near future.

RDT&E, N becomes real

With passage of Public Law 86-166 on August 18, 1959, the Department of Defense and its constituents were provided funding to operate through the fiscal year ending June 30, 1960. Title IV dealt with funding for research, etc., and included, not only Army and Air Force, a section titled "Research, Development, Test, and Evaluation, Navy." RDT&E, N was now a reality.

While it may have been real, it was unsettling and distressing for many in the Navy lab community. In a May 1960 speech to the American Ordnance Association, Naval Ordnance Test Station's Dr. William B. McLean begged attendees to "find some way to rescue the design of our military equipment from the morass of integration, coordination, centralization, and detailed specifications to which it is sinking."[17] A year earlier, he had spoken at a conference on research administration, presenting perhaps for the first time his nine methods for rapidly changing "a creative organization into one doing only routine productive work."

[17] *The Station Comes of Age,* 300.

The two most pertinent of those to this discussion were:

> 1. Coordinate work carefully to avoid duplication. (Everything new can be made to look like something we have done before, or are now doing)…7. Centralize as many functions as possible. (This creates more review levels and cuts down on direct contact between people.)[18]

His rationale reflected substantial personal experience in maintaining creativity, as suggested in Volume 4 of the China Lake history, that "… products like Sidewinder, Walleye, Shrike, and numerous other successes would never have seen the light of day in an 'efficient' organization, one in which every penny was spent precisely as the Washington managers had ordered."[19]

It wasn't so much a matter of McLean getting what he wanted as it was getting what he believed the Navy needed. As Dr. Howard Wilcox, who took over management of Sidewinder development from him, put it: "… he didn't accomplish as much as one percent of what he would have accomplished if the Navy had backed him strongly. If the Navy managers had given him money and authority, he would have accomplished a great deal more for them than he did."[20]

(To a degree, as a matter of fact, Wilcox was one of those "Navy managers" while serving as deputy DDR&E. It was an assignment not much to his liking, however, and after a couple of years in Washington, he severed his Civil Service connection and went to work for General Motors. And then came back again!)

The import of the RDT&E, N appropriation was most significant in heralding the planned centralization philosophy of the early defense secretaries had arrived. Rawson Bennett had been most certainly correct in his statement to that effect.

Challenges compounded

Eisenhower's successor, John F. Kennedy, compounded the challenge to the China Lake philosophy of creative R&D by selecting a private industry leader, Ford Motor Company president Robert S. McNamara, as his Secretary of Defense. As a cheerleader for his most cherished cause, McNamara might have chanted, "Give me an 'E' for 'efficiency!'" While his philosophical bent was displeasing to

---

[18] "Nine Ways to Ruin a Laboratory," *The Station Comes of Age*, Appendix B, 681.
[19] *Station*, 301.
[20] DNL History Study interview of Dr. Howard A. Wilcox, 7.

McLean and other members of the China Lake leadership, he certainly took on some issues of importance to them in his generation of 120 questions/topics seeking to improve the military. One in particular, Question 97, resulted in an identically numbered task that requested, "Advise me on ways in which to improve the operations of the in-house laboratories." The study was taken on by Howie Wilcox's successor as deputy DDR&E, Dr. Eugene Fubini. His report, issued in 1961, "noted several problems with DOD laboratories: low morale, non-competitive salaries, substandard physical plants, and difficulties with executive management due to dual leaderships (civilian and military) and lack of technical qualifications."[21]

Reasonably, the laboratories were important to McNamara, since, according to the Center's fifty-year history summarization of the Fubini report, they

> could investigate rapidly changing technologies for their applicability to military problems… could bring military needs to the attention of the general scientific and technical community… enabled the services to be 'smart buyers' of contract R&D… managed and helped manage weapons systems development and test programs… developed a cadre of technically proficient military officers necessary in the modern armed forces.[22]

Fubini's report cited clearly inter-related problems in the laboratory system (specifically the Navy's), including over-dependence on bureau sponsorship; inordinate time and effort by project managers to gain sponsor funding; more time spent on contract monitoring than on in-house research and development; and difficulties in recruiting top technologists in light of much higher industry salaries.

Both McNamara and his DDR&E Harold Brown championed Fubini's report and recommendations. As a result of those recommendations, the Navy directed its material bureaus to support independent exploratory development as a budget line item in 1963, and added an additional budget line item for independent research the following year.[23]

The Navy had something existing titled "Foundational Research" long before McNamara. Early on, it was pursued exclusively at the Bureau of Ordnance labs,

---

[21] U.S. Department of Defense. Task Force 97 Action Group. "Review of Defense Laboratories: Progress Report and Preliminary Recommendations," (Fubini Report), September 1961. Quoted in: Robert V. Gates, Ph.D., "History of the Navy Laboratory System," *International Journal of Naval History*, April 2013, Volume 13, Issue 1.

[22] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma, 1940-1990*, NOSC Technical Document 1940, 1990, 59.

[23] *Fifty Years*, 59.

NOTS China Lake and the Naval Ordnance Laboratory in Maryland. As detailed in Chapter 4, the BuOrd chiefs, while practicing the tight control of their bureau brothers, followed a decidedly different approach to their labs, listening to their ideas and approving with the most effective response—funding. With McNamara's initiatives, "Independent Research" was promoted at all Navy labs.

Directing and controlling

A few months before Fubini's report was issued, in July 1961, another of McNamara's key personnel, Assistant Secretary of Defense (Comptroller) Charles Hitch, introduced his Planning, Programming, and Budgeting System (PPBS). Intended for implementation in the FY1963 budget, "Its major objective was to overcome alleged weaknesses in the existing financial management procedures and to provide a tool for overall direction and control of the defense effort."[24]

"Programming" sought to aggregate DoD programs and all service activities into "program elements," i.e., integrated combinations of personnel, equipment, and facilities "whose effectiveness could be related to military objectives."

Those elements were to be combined further into major program packages with all physical and financial data, "projected five years ahead and incorporated into a Secretary of Defense-approved" Five Year Defense Plan (FYDP, generally pronounced "fid-ep." It became a common term in program and funding discussions in the acquisition community, including at the defense laboratories.) Inclusion of a proposed technical program in the plan didn't guarantee funding, but those not included were essentially assured of no funding.

As an important off-shoot of the FYDP, following the publication of Fubini's report by two months, DDR&E Harold Brown provided a major addition to the mix with his identification and promulgation in November 1961 of the six "RDT&E categories" that would guide the thinking of DoD laboratory management and technologists for decades.[25] In those categories, he sought to

---

[24] *Review of Navy R&D Management*, 209.

[25] Memorandum, Harold Brown, DDR&E, to Service Secretaries. Subject: Structure of Research and Development Programs. November 6, 1961. The initial memo proposed five categories. The sixth, Operational Systems Development, was added during coordination of the proposal with the services.

provide consistency in the workings of the military services, which pursued various approaches to technology development due to real or imagined differences. In addition to the usual NIH (Not Invented Here) reasoning, there certainly were decided differences between a Sherman tank, an aircraft carrier, and a B-52 bomber. On the other hand, the military services were fairly consistent in understanding precisely what technologies might benefit their respective platforms, developing them to a reasonable point, and then turning to private industry to manufacture five or eight or a hundred of them to the service's specifications. And in point of fact, it is not unreasonable to suggest commonality of developmental strategies that appear to be substantially different merely because they have other names, or different definitions, or varying terminology.[26]

Seeking to standardize (a common thrust in both the McNamara and Brown DoD administrations), Brown, in concert with the service secretaries, developed a construct of six elements representing milestones in the progressive RDT&E functions leading to new military technology. Those functions were 6.1: Research; 6.2: Exploratory Development; 6.3: Advanced Development; 6.4: Engineering Development; 6.5: Management and Support; and 6.6: Operational Systems Development.[27] With minor refinements (most notably, division of Advanced Development into 6.3A and 6.3B, then re-numbering them 6.3 and 6.4; the rest became 6.5, 6.6, and 6.7), and some name changes, those categories persist to the present (2020). As the "study of studies" claimed, "In terms of its impact on the R&D program planning process, the six-part program structure was one of the most fundamental and pervasive of the changes introduced in the early 1960's."[28]

While the development of such things as "categories" is particularly valuable for those seeking control, it does not necessarily eliminate complexity, and it certainly did not do so in preparation of something as complicated as the massive budget of the Department of Defense. One (of many) of the fundamental difficulties in preparing the budget was "differentiating between development and procurement. As a purely technical matter of definition, it was difficult enough to determine where development stopped and procurement began."[29]

---

[26] It is interesting to note that President Truman, two years before signing into law the National Security Act of 1947, had suggested the idea of combining the military services into a single unified command, which might have obviated those different approaches.
[27] *Review of Navy R&D Management*, 210-211.
[28] *Review*, 221.
[29] *Review*, 282.

And, as always, the Navy bureau chiefs had a variety of opinions on that differentiation. Compounding that was their

> deep fear of incursion of T&E into available funds for R&D. The inclusion of T&E seemingly increased absolute dollars spent for R&D, but inherently greater costs for development and T&E might serve to reduce the proportion of funds spent on the R&D end of the spectrum.[30]

And those costs, reasonably appearing throughout the technology development cycle, were often not inconsequential, according to retired Naval Information Warfare Center Pacific Executive Director Carmela Keeney, commenting on that several decades later:

> T&E exists in 6.3 through 6.7, but the focus/type of T&E changes. In 6.3 it includes laboratory testing, T&E in simulated environments. In 6.4 it includes testing prototypes in more realistic environments. In 6.5 it includes TECHEVAL and OPEVAL… T&E is very expensive, especially when it involves testing in operational environments with things like ships, aircraft, test ranges, etc.[31]

As noted, the Navy's bureau chiefs reacted in differing fashions to McNamara's efficiency-or-else policies. In probably the most radical response, and certainly the most publicly noted (New York *Times*, October 29, 1965), the chief of the Bureau of Ships, Rear Admiral William A. Brockett, actually resigned in October 1965 in protest, as did his deputy, Rear Admiral Charles A. Curtze.

Valley of Death

One critical point should be made here: despite linear progression of numbers (6.1, 6.2, etc.) and similar gradations of "development" (exploratory, advanced, engineering), the process of fielding new technology was/is not a smooth continuity. One of the most significant aspects of the development process is described fairly pointedly as "the Valley of Death." In terms of Harold Brown's six—later seven—categories, it separates 6.1-6.3, generally considered "science and technology," from 6.4-6.7, which in Brown's day was described as "procurement," but which several decades later would be called "acquisition."

In a typical scenario, a Navy lab such as the Navy Electronics Laboratory or the Naval Ordnance Test Station would "invent" and develop a promising new

[30] *Review*, 283.
[31] Carmela Keeney email to Tom LaPuzza, May 14, 2020.

technology to a certain level of maturity, using various sources of funding such as the Office of Naval Research or the Advanced Research Projects Agency. At this critical juncture, it was necessary for a program official of one of the Navy's bureaus to step forward with the additional (and usually much greater) funding to push the technology into the acquisition process. (With the demise of the bureaus, this responsibility fell to the systems commands, and, somewhat later, to the Program Executive Offices [PEOs].) Without that push, the technology usually died: "Many great things that are invented and developed in S&T never make the transition from S&T to acquisition."[32]

PPBS shifts control

The PPBS devised by Assistant SecDef Hitch was conceived as a solution to the problem of military planning with little attention to cost, and budgeting without connection to potential military capability. He claimed his management tool would not only enhance the ability of top-level DoD officials to make (financially and programmatically) wise decisions by relating resource costs to military missions, but also generate substantial, accurate, and in-depth data and financial information. As had been feared by many at the service level, particularly Navy: "The introduction of PPBS, in sum, resulted in decreased program management control and flexibility at the operational level in direct proportion to increased management control at the OSD level."[33]

Despite some concern, Hitch's system produced positive results in relation to complex budget development: "… a significant side effect of the PPBS was the introduction of modern data processing techniques into the budget process."[34]

Navy Industrial Fund

Prior to the push for uniformity and centralization, the military services under

---

[32] Keeney email of May 14, 2020.
[33] *Review*, 305.
[34] *Review*, 301.

the War Department developed and operated a number of financial systems. The Navy, in particular, recognizing substantive differences between a shipyard, a destroyer squadron, and an R&D lab, employed a variety of accounting systems. Based on high-level interest (including the President) in use of commercial accounting practices for the U.S. government, Defense Secretary McNamara announced adoption of such practices for his department in August 1966, titled the Resource Management Systems (RMS). His stated "ultimate goal was to encourage greater cost consciousness and efficiency." His objectives included "an integrated financial system for planning, programming, budgeting, and accounting"; identification and costing of all program resources; and "uniformity in classification of financial transactions, accounting, and reporting."[35]

RMS covered three categories of expenditures: operations and maintenance, including appropriations for military personnel; procurement and construction investment; and research and development. The latter, which went into effect in January 1968, was initiated to identify all actual R&D costs, a number of which traditionally had been reported elsewhere and thus "hidden" as to actual purpose.

Bob Frye, who as comptroller served as the top financial officer of the Navy laboratory on Point Loma from 1989 until 2004, explained the process:

> In the early years of the Command… all of the financial budgeting and records were done using appropriated funding using Resource Management System[s] (RMS). Budgets involved accumulation of data, writing of justification and the preparation of forms for everything the Command was to perform for the following years. Most of the funding requested was Operations and Maintenance, Navy (O&M, N) in those years for payment of salaries and the performance of the mission.[36]

A major feature of RMS from the Navy standpoint was "institution of either Navy Industrial Fund (NIF) accounting systems or an equivalent working capital fund arrangement at all R&D activities unless specifically exempted."[37] In point of fact, NIF was one of the Navy's various accounting systems substantially pre-dating McNamara's RMS: "NIF had been introduced into NRL [Naval Research Laboratory] and NOL [Naval Ordnance Laboratory] as early as 1953 and used in the Navy shipyards even earlier."[38] According to Frye, who worked in financial management at NOL for a decade prior to transferring to the Point Loma lab:

---

[35] *Review*, 306.
[36] Bob Frye email to Tom LaPuzza, November 14, 2014.
[37] *Review*, 307.
[38] *Review*, 163.

> NIF was based on a concept similar to the commercial world where [a Navy] Command would budget all its operating costs to perform its programmatic mission and to recover all of its operational costs from customers or sponsors using overhead rates. Overhead rates were applied to hours worked on specific direct projects a Command executed for its sponsors… At a simplified level the NIF activity would incur cost for labor, materials, travel, etc. which was paid for out of what was called a 'corpus' that was given to each activity. As these costs were recorded against projects the customer or sponsor would be billed for the costs [to] replenish the corpus. In effect the corpus would… be considered cash in the private sector.[39]

Frye enumerated three major categories of costs: direct costs connected to a specific project or program, production overhead costs related to overall management of a group of projects, and general overhead: "These costs covered such things as the Command infrastructure and staff organizations supporting things like base operations, personnel, finance, supply and contracting."

In the long term, industrial funding sought several beneficial outcomes: 1) to charge the most appropriate sponsor/customer the full cost of the services provided; 2) to include in that not only the costs of equipment purchased, contracts let, and the direct labor charges of technical personnel, but also the indirect costs of managers and support personnel, depreciation, etc.; and 3) to provide Navy laboratories with a reasonably regular funding stream from year to year.

Since a common funding system promised to promote financial efficiency and a more business-like approach to project work, Chief of Naval Material (CNM) Admiral I.J. Galantin recommended conversion of all his R&D laboratories to NIF, "which was more appropriate for multifunded activities." Recognizing the need to prepare for that, the Naval Electronics Laboratory Center hosted a NIF orientation seminar on Point Loma in January 1969, attended by 250 people from twenty Navy laboratories. Timing was fairly good: "[This] was implemented on 1 July 1969 with the conversion of the 12 major CNM R&D laboratories to NIF."[40]

In the late 1960s to the early 1970s, both the Resource Management Systems and the Navy Industrial Fund were employed for budgeting and accounting at the Navy's labs. "Over a few years the RMS effort was completely phased out in favor of the NIF," according to Frye. The Navy's title for the fund changed over time, from the original Navy Industrial Fund (NIF, which humorists and serious accountants alike equated with "Nothing Is Free") to Defense Business Operations Fund (DBOF) and later Navy Working Capital Fund (NWCF).

[39] Frye email of November 14, 2014.
[40] *Review*, 307.

An interesting issue emerged related to military salaries and benefits: Under NIF guidelines, sponsors were charged for *all* costs, including those of military personnel. The Army and the Air Force maintained military personnel were *free*. This was not only a sticking point with the other services; when the San Diego-based Eleventh Naval District sought military personnel from the Point Loma lab for various reasons, the first question was: "Who is going to pay for them?" To which the region spokesman replied: "Navy uniformed personnel are free!"

Jeff Grossman, a psychologist who led human factors research work on Point Loma for decades, offered this explanation:

> The Navy bureaucracy does not understand the laboratory system and how it operates. They have never understood industrial funding, which was the biggest problem I had in the 40 years I worked here… You have to live it. It seems to me that having a government bureaucracy manage an industrially funded system is a recipe for inefficiency and ineffectiveness… You have to have some kind of understanding but I just don't see that people ever understood it until they lived it somehow. Because the labs are run like a business but with government rules.[41]

STAFS follow-on

In the early 1980s, the Navy initiated another major effort for financial data reporting, which was titled the Standard Automated Financial System.[42] Centered physically at the Point Loma lab, at the time the Naval Ocean Systems Center (NOSC), it was viewed with substantial optimism which in the long view proved to be ill-founded. The major positive was NOSC leadership of the effort qualified it for substantial contributions to a Navy financial management reorganization in the early twenty-first century, termed Enterprise Resource Planning/Project Cabrillo, which will be discussed in Volume II.

Rear Admiral Bennett recalled to duty

During this period of numerous studies and analyses, Rear Admiral Rawson

[41] Jeff Grossman SSC Pacific oral history interview conducted by Tom LaPuzza, August 2, 2012, 6-7.
[42] Naval Ocean Systems Center *Outlook*, November 6, 1981, 3.

Bennett completed five years as Chief of Naval Research and retired in early 1961 after a lengthy, illustrious career. His retirement was short-lived, however; a year and a few months later, he was recalled to active duty. As was his way, he vigorously pursued his task as director of the Research and Development Study Group for the Management of the Navy Department until the end of the year, when he retired for good. The study group issued a report identifying problems similar to those cited in the Fubini report and others experienced only by the Navy.[43] The report, part of a larger study of overall Navy management practices, included a warning about anticipated higher-level review of service programs: "Defense approval of proposed programs will be on a highly selective basis… Navy RDT&E programs will have to be extremely well founded."

The Navy-unique difficulties were based almost exclusively on the service's bilinear structure for technology acquisition. As Naval War College historian Dr. Robert V. Gates explains, the Navy had for decades supported a structure in which the "users" of weapons and other technologies, essentially the people in uniform, reported up a chain headed by the four-star Chief of Naval Operations, who reported himself to the Secretary of the Navy. Those responsible for acquiring technology, either through their own development efforts or by purchasing them from private industry, reported to a bureau chief, one of the previously identified "platform barons." They were flag officers also reporting to the Secretary, but they had no legal responsibilities to the CNO, despite all having fewer than four stars.[44]

In a report several years before the Bennett group convened, Undersecretary of the Navy William Franke had advocated retention of the Navy's bilinear structure philosophy.[45] Despite the various challenges the structure posed, it was seen by many as a reasonable approach to managing complex Navy procurement.

Among other findings in the Bennett study were lack of "truly expert" personnel, both military and civilian (it was certainly not surprising people like Stanley Hooper, Levering Smith, and Bill McLean were few and far between); lack of strategic thinking for Navy technology development; and challenges to early-stage research, given greater interest in development. (Gates contends reasonably bureau chiefs were more interested in improving existent technology

---

[43] "Research and Development Management Study," *Review of Management of the Department of the Navy,* Volume II, Study 3, 19 October 1962.
[44] Gates, "History of the Navy Laboratory System."
[45] Department of the Navy, "Report of the Committee on Organization of the Department of the Navy," 31 January 1959.

than paying for basic research that would take years to produce something useful, by which time they would be long gone.) The study recommendations included one that would surface, in a slightly different fashion, several years later: establishment of a position to oversee the bureau chiefs, the suggested title for which was Chief of Naval Logistics.

In fact, the Secretary of the Navy assigned that responsibility for Navy bureau coordination to the Chief of Naval Material in 1963. That officer, like the bureau chiefs, reported directly to him, with no responsibility to the Chief of Naval Operations, thus effectively continuing the bilinear structure.

Studies continue

The era of studies continued, as Chalmers Sherwin, successor to Dr. Fubini as Deputy DDR&E, published in late 1964 two "plans" for the in-house laboratories. For Navy labs, it was a "proposed" plan for "organization" (read "reorganization") suggesting installation of a civilian director reporting to the assistant secretary for Research and Development (ASN [R&D]), with nine R&D laboratories reporting to him, including the Point Loma electronics laboratory and the desert ordnance laboratory. Although Navy leadership agreed with a number of Sherwin's points, the proposal's organizational element met with resistance. By way of a response, perhaps, the service commissioned two studies—one by a flag officer and the other by ASN (R&D) Robert Morse —pushing for the status quo of the bilinear organization and, in the case of Morse's, maintaining the bureau-laboratory connection.[46] The ASN did agree with the concept of a lab director, which he viewed on a level with the Chief of Naval Research and Chief of Naval Development; those were flag officer, not civilian, assignments. A very significant aspect of that study was the proposal to provide block funding to the laboratories.

The study and report of DDR&E Dr. Fubini was cited above; his findings noted several challenges of the Navy labs in funding project work. One potential solution to those was the concept of allocating a credible amount of funding for exploratory development investigations in specific areas, for example, guided missile propulsion and ASW. Such a "block funding" concept would preclude, or at least substantially lessen, the necessity of Navy project personnel spending

[46] Robert W. Morse, "On the Management of Navy Laboratories," 4 January 1965.

inordinate amounts of time seeking project sponsorship in specific areas of technology. It would increase time and attention to pursue actual technology development goals; it might also decrease the competition McNamara's DoD shunned. Another benefit would be to preclude year-end scrambling for carry-over or start-up dollars to fund Navy scientists and engineers at the end/start of fiscal years. While block funding provided some value in a limited number of technology areas, e.g., undersea surveillance, its opponents (bureaus/systems commands), rejected it as a workable alternative to industrial funding.

Century-old Navy bilinear structure replaced

With a plethora of studies behind them (but certainly many more to come), the Navy Department initiated major actions in late 1965 to early 1966: establishing a formal position of Director of Navy Laboratories (December 1965, SECNAV Instruction 5430.77); replacing the bureau structure with systems commands; and replacing the Naval/Support Establishment with the Naval Material Command, the commander of which would report to the Chief of Naval Operations rather than to the Secretary of the Navy. And most significantly,

> The 1966 reorganization eliminated the bilinear organization structure which had served the Navy for more than 100 years. Under the terms of the reorganization, the Chief of Naval Operations assumed direct line authority over the material organization. This action ratified a trend that had been in motion since the late 1940's.[47]

The announcement from the Honorable Paul H. Nitze was printed in full in the Navy Electronics Laboratory's newspaper, beginning:

> The Secretary of Defense has approved my proposal of 4 March for a reorganization of the Navy. This reorganization will increase the breadth of authority and responsibility of the Chief of Naval Operations under the continuing direction of the Secretary of the Navy and will strengthen the management of the Navy's material support organization."[48]

The statement went on to provide details on the restructuring of the Naval Material Command organization from its current four bureaus into six systems commands: air, ship, electronic, ordnance, supply, and facilities engineering. Under the new structure, the CNO would exercise authority over not only these

---

[47] *Review of Navy R&D Management*, 91.
[48] NEL *Calendar*, March 11, 1966, 1.

organizations, but also over the Chief of Naval Personnel and the Chief of the Bureau of Medicine and Surgery.

Of the five reorganization "purposes" cited by the NEL article, two were indicative of the hand of the SecDef behind such actions: "Centralize… RDT&E management," and "Increase… efficiency and economy…" Significant for the two Navy laboratories in this history was the plan to "give more emphasis to ordnance and electronics." Interestingly, in light of the various shuffling of organizations (as well as its title), NEL was not assigned primary responsibility to the new electronic systems command: "Navy Electronics Laboratory now reports to CNM and receives all support from Naval Ship Systems Command."[49]

The Navy action assigned the new director of laboratories to the office of the assistant secretary. It stipulated specific responsibilities, including additional duty as Director of Laboratory Programs in the Office of Naval Material, such that the first person offered the job turned it down as "awkward and perhaps untenable."[50] Dr. Howard Wilcox, who had worked at NOTS China Lake for a decade and served as the first Deputy DDR&E, was working in private industry when he "was brought into Washington and wined and dined… to be DNL, the first DNL. I took one look at the job and said, 'No, thanks.'"[51] Wilcox, directing research and engineering for General Motors laboratories in Santa Barbara at the time, believed the position would add to the already "almost crushing weight" of bureaucracy on people like Navy laboratory technical directors, with no constructive impact.

The director eventually appointed was Dr. Gerald C. Johnson, later succeeded by Dr. Joel S. Lawson. One of their significant challenges was responsibility for technology development without the necessary funds, since the majority of those monies were controlled by the Navy bureaus and their successors, the newly created systems commands. "In reality, the Office of DNL could not materially influence technical programs because the programs were not funded by DNL."[52]

Over the years, two individuals associated with the Point Loma Navy laboratory would be DNL: Robert M. Hillyer and Dr. Ed Tunstall, both of whom will be discussed in detail later in this history. Hillyer, who was taken "kicking and

---

[49] "Secretary of Defense Order Activates Naval Commands," NEL *Calendar*, May 13, 1966, 2.
[50] According to Gates, "History of the Navy Laboratory System," that individual was Gregory Hartmann, Naval Ordnance Laboratory technical director.
[51] Howard Wilcox DNL interview, 21.
[52] *Fifty Years of R&D*, 60.

screaming" from his position as technical director at China Lake to be DNL, got some payback, he claimed, by later appointing himself as TD of the Naval Ocean Systems Center (NOSC) on Point Loma. Tunstall left his position as head of the NOSC Command and Control Department to become TD of the Naval Coastal Systems Center in Florida (coincidentally recommended for that position by Hillyer). From there he became DNL, also under pressure.

Pasadena Lab saga

With project work on Polaris and ASROC detailed in the previous chapter, Pasadena's personnel and funding numbers grew significantly. What failed to keep pace were facilities. Norm Estabrook—a long-time ocean engineer at various Center sites— arrived in early 1963 for a job interview, hoping to be selected as a Junior Professional, and had this reaction to a tour: "…he took me around and showed me the place, and, of course, Pasadena annex was a dump! I mean, it was formerly an old orange crate factory, and it wasn't much of a facility…"[53]

Inadequate facilities were among the significant findings in the Fubini report on McNamara's Task 97 and, to a lesser degree, in Rear Admiral Bennett's 1962 study. For Pasadena, it was a problem dating back more than a decade. Archive documents as early as 1950, shortly after the conclusion of the General Tire and Rubber Company contract to manage the facility, reported plans to develop a new laboratory site with modern facilities in the San Gabriel Canyon-Azusa area, a short distance from the NOTS Morris Dam site.

A 15 September 1951 submission to an unnamed higher authority called for purchase of four acres of land west of the Pasadena location on Foothill Boulevard and construction of a laboratory and office building, a separate laboratory, and a cafeteria. Stated purpose was to facilitate consolidation of personnel and closing of facilities at locations on Green Street, where the headquarters and R&D office spaces were housed in a building of "poor structural condition," and at McCormack General Hospital. The latter, a decommissioned Army hospital, was pressed into service during the Korean Conflict for offices, shops, and labs.

---

[53] Norm Estabrook Naval Weapons Center interview conducted by Leroy Doig III, 9 August 2011, 1.

Between Fiscal Year (FY) 1954 and FY60, the same background information and request for construction funds were submitted annually to higher authority, with some revisions but no positive result.

In the fall of 1955 and again in the spring of 1959, major proposals were submitted for construction of an office/laboratory building(s) to satisfy what were universally characterized as the "urgent" need for new and enlarged facilities.[54]

In fact, at a Pasadena Annex all-hands meeting in October 1956, employees bombarded the officer-in-charge, Commander J.J. O'Brien, with questions about the "projected move to Seal Beach." He responded by explaining levels of approval required and potential for delays, concluding the earliest probable date for the move would be 1961. Since the building groundbreaking would occur at least a year before, he recommended "employees wait until that time before taking any steps toward changing residence." The wording of the station newspaper article indicates uncertainty on timing only, not to the decision to move.[55]

"…sub-standard shacks… bewitching problem…"

Some documents related to facility improvement or replacement are humorous in retrospect. For example, a proposal from an architectural engineering firm in 1958 for the Paul D. Stroop Laboratory of Underwater Sciences states,

> So intolerable are these working conditions, wherein highly trained-personnel are unable to function at their optimum-best [sic] in the interest of the national defense, and wherein any anticipated enlarged missile-testing program will only add to this inefficiency and confusion… The existence of many other sub-standard shacks… The bewitching problem to be resolved, was the interplay of classified and non-classified individuals using the building simultaneously.[56]

Particularly noteworthy was the report of an in-house analysis group to the

---

[54] U.S. Naval Ordnance Test Station: "Laboratory and Office Building, Pasadena Annex," 1 October 1955; Commander, U.S. Naval Ordnance Test Station memo to Chief, Bureau of Ordnance, P12/5010/Ser. 1486 dated 6 Apr 1959.

[55] NOTS *Rocketeer*, October 26, 1956, 3.

[56] Norman B. Entwistle, Architect A.I.A., "Paul D. Stroop Laboratory of Underwater Sciences, U.S. Naval Ordnance Test Station," June 1958. (The assumption is that someone at the Pasadena Annex provided the building title, honoring the fifth commander of NOTS, Vice Admiral P.D. Stroop, who had gone on to command the Bureau of Naval Weapons, the station's major sponsor.)

Pasadena officer-in-charge, tidily summarizing the previous studies: "1950 Pasadena-San Gabriel-Azusa Study, 1956 Seal Beach Study, 1957 Corona Study, 1958 Pasadena Study, 1959 Corona Study, 1960 Point Loma Study, and 1961 Pasadena Study (current)."[57]

A brief discussion of an ASW lab combining NOTS Pasadena with NEL in San Diego ended with a disagreement about who would be in charge of what.

In the fall of 1962, NOTS Commander Captain Charles Blenman wrote to his boss at the Bureau of Naval Weapons, providing a different approach.[58] He addressed the previous NEL consolidation proposal, citing "changed conditions" which "caused this Command to re-evaluate the desirability of various sites" for locating the lab facilities, claiming, "A more favorable environment for underwater weapons research and development exists in the Pasadena-Los Angeles area…" Enclosed was a booklet explaining the new proposal, detailing close availability of test ranges at Morris Dam, Long Beach, and San Clemente Island; proximity of universities; and the ample manufacturing capabilities of the greater Los Angeles area.[59] The proposal refuted point by point advantages cited for a move to Point Loma. Also mentioned were increased work on Polaris testing, re-allocation for another purpose of Point Loma land promised for a missile-assembly area, and anticipated loss of essential personnel declining to move.

Proceeding on the LA-area plan, the Bureau of Yards and Docks conducted a survey of potential lab sites. Its report, published in June 1963, detailed evaluation of nineteen potential sites, narrowing choices down to four "feasible" ones: the current Pasadena location, Naval Air Station Los Alamitos, the Naval Weapons Station at Seal Beach, and a private site a few blocks east of the Annex.[60] Based on

---

[57] Management Analysis Group, Code P1902, memo to the Officer in Charge, Pasadena Annex, 18 August 1961.

[58] Official letter from Commander, U.S. Naval Ordnance Test Station to Chief, Bureau of Naval Weapons, Serial 3731 of 17 September 1962, Subj: Underwater Weapons Laboratory, U.S. Naval Ordnance Test Station, Pasadena Annex; proposal for.

[59] U.S. Naval Ordnance Test Station, China Lake and Pasadena California, "Proposal for NOTS Underwater Weapons Laboratory," September 1962, 14-18.

[60] Southwest Division, Bureau of Yards and Docks, San Diego, California: "Site Selection Study for Proposed NOTS Underwater Weapons Laboratory in the Los Angeles-Pasadena Area," 18 June 1963.

The NOTS Pasadena facility, shown in this 1964 photo, was variously described as “an orange crate factory” and a collection of “sub-standard shacks.”

savings of major construction costs and the reasonable ability to sell the Foothill property, the report recommended Seal Beach. Reassurance was given the number refusing to move would be small, and could be further reduced by appropriate action:

> While it is realized that a few employees may be lost because of personal reluctance to relocate, it is believed that this reluctance can be overcome to a great degree by promptly advising all personnel of the final site selection, if other than the present location.

The authors of the study lacked the fairly overwhelming data that would result several decades later during base closures of the 1990s, that a substantial majority of employees involved in such closures would decline to move. Annex employees, who had faced the identical proposal/threat of a forced move to Seal Beach seven years earlier, had voiced significant opposition then, and certainly would again.

The Congress provided some measure of encouragement (and hope) in its passage of the appropriation bill for military construction in 1963, allocating $17,300,000 to the Navy for general support programs. Its sole direction in that appropriation was a clear demand to the Navy Department to manage the challenges facing the Foothill Boulevard facility: "The Committee expects the Navy to utilize a portion of these funds for the planning and design of facilities to replace the inadequate facilities at Naval Ordnance Test Station, Pasadena, California."[61]

Subsequent investigations revisited the Pasadena vs. Point Loma (or other San Diego) sites and concluded a move south would be expensive in terms of construction costs, loss of personnel, and increased travel requirements to reach essential test sites; scientific interchange and sharing support costs with NEL were cited as advantages.[62] The proposed alternative was razing the present inadequate buildings at Foothill and constructing a six-story building on the site.

While Pasadena lab managers and higher authority saw substantial shortcomings, not everyone agreed. Augie Troncale, hired in the late 1960s under the New Technician program, served as an aircraft carrier sailor, then spent half a dozen years in those labs. He considered them fairly typical of current facilities:

> When I returned from military service in 1970, I worked at the Pasadena lab—extensively in its labs and shops and in the Long Beach and Morris Dam test facilities. I believe the shops were very representative of similar shops throughout the area at that time. Most hardware shops and test facilities at that time still had a WWII look and feel. Our shops were equal to those I went to throughout the LA area and the country… However our labs did not have some of the new and updated infrastructure such as ventilation that was in the newer labs in the 1970s. The 1970s saw a major initiative to incorporate improvements in the safety and quality of labs and shops especially in the environmental areas.[63]

Underwater Weapons Laboratory

The studies mentioned in the last several pages were specifically geared to

---

[61] U.S. Congress, Military Construction Appropriation Bill, 1963, 15.
[62] "Comparative Analysis of Proposed U.S. Naval Ordnance Test Station Facilities at Pasadena vs San Diego Area." Prepared by U.S. Naval Ordnance Test Station, China Lake, California, 4 December 1964; and Albert C. Martin and Associates, "Feasibility Study of Expansion Potential for Underwater Weapons Laboratory," April 5, 1965.
[63] Augie Troncale email to Tom LaPuzza, March 8, 2017.

replace aging, inadequate facilities at Pasadena. A more ambitious plan had surfaced in 1959, one that would eventually come to fruition, but only after almost two decades of studies, planning, and counter-planning. In that plan, NOTS Technical Director Dr. William B. McLean had suggested the value of establishing a test station laboratory dedicated to undersea warfare. A firm believer that the future of the Navy, offensively and very certainly defensively, lay in the underwater realm, he envisioned a “1000-man” facility to carry forward the substantial ASW achievements of the Pasadena Annex. In response to McLean’s suggestion and later discussions, NOTS Commander Captain William W. Hollister had supplied data to his superior, the chief of the Navy’s Bureau of Ordnance, relative to a formally titled Underwater Weapons Laboratory (UWL), to be situated on Point Loma in San Diego.

Coverage of the lab situation in the Pasadena section of the *Rocketeer* later in the year reported the officer-in-charge, Captain Charles J. Beers, had advised his employees at an all-hands meeting: “We will not be moving to Point Loma until at least after 1962. The Point Loma move did not get on the 1961 budget, and the next chance for it will not be until the 1962 budget is considered.”[64] Based on his statement, it seemed reasonable to assume, as had occurred with the earlier projected move to Seal Beach, that it was just a matter of time before the announcement of a required move to San Diego.

As noted above, a month after that article appeared, Pasadena staff personnel met with their opposite numbers from the Navy Electronics Laboratory to discuss a potential relationship, with some agreement on combining support functions, but disagreement as to who would be in charge of the merged services. This difficulty derailed plans for establishment of the lab temporarily, but members of China Lake’s Central Staff had the wisdom and foresight to document the initial planning effort for future reference:

> Although, at this time, realization of the Laboratory is probably several years away, we should have an organizational blueprint to serve as reference point and indication of management’s present intentions. Already, in having had to answer BUWEPS questions of proposed organizational relations to the Naval [sic] Electronics Laboratory at Point Loma, such a blueprint would have been useful… Finally, in pursuing this study, the question of UWL’s general tie-in with the national ASW effort has arisen importantly and is dealt with herein.[65]

---

[64] NOTS *Rocketeer*, November 13, 1959, 3.

[65] U.S. Naval Ordnance Test Station, “Organization Study of the Proposed Underwater Weapons Laboratory Point Loma,” December 1960, 1.

ASW lab planned: HQ at China Lake, lab on Point Loma

The report was based on interviews with NOTS and NEL management and NOTS personnel working in ASW. "Basic assumptions" emerging from those interviews were that UWL organizationally would be part of NOTS, whose headquarters would "probably" remain at China Lake; the proposed facility would be a "1,000-man" [sic] laboratory; Point Loma would be the focus of the ASW effort, but there would be other venues (almost certainly San Clemente Island, possibly Morris Dam). In a section on military personnel, there is an intriguing mention their responsibilities would include "manning the proposed deep-sea research vehicle," with no details.

Perhaps the most critical piece of the plan was that the major staffing of the new lab would be personnel transferring from Pasadena.[66] The fairly lofty goal, which undoubtedly reflected William McLean's thinking on the subject, was that

> NOTS, and more particularly UWL, will be fulfilling an ever-increasing role in ASW research and development. This is especially true considering the greater part to be played by NOTS in weapons planning and research at Point Loma and the fact its efforts in that location will be more effectively complemented by NEL, Scripps and the Fleet. This complex will tend to be in fact, if not formally, a West Coast ASW Center.[67]

McLean understood the benefit of bringing the "local" (i.e., southern California) community of ASW expertise together. He couldn't have the China Lake "creative isolation" environment he cherished in San Diego, but he (and more importantly from his perspective, the Navy) would have powerful resources to counter the submarine threat at a laboratory based in San Diego. NEL at the time had its own submarine for validating underwater sensing devices, USS *Baya* (AGSS-318), an excess World War II boat that had been provided for the laboratory's exclusive use. Its current mission was testing the promising Long-Range Active Detection (LORAD) sonar. The lab also had several WWII patrol escort craft to support *Baya* and carry lab scientists to sea. Foremost among those scientists were Dr. Waldo Lyon, Dr. Eugene LaFond, and Bob Waldie, who were doing cutting-edge submarine-related research.

Additionally, the Marine Physical Laboratory (MPL), located in one of the NEL waterfront buildings, was doing important underwater research under the

---

[66] "Organization Study…" December 1960, 3-7.
[67] "Organization Study…" 20.

direction of Dr. Carl Eckart, who had formed it shortly after the carefully orchestrated disestablishment of the University of California Division of War Research. It was "shortly after" because the Navy balked at sponsoring a specific organization with a specific individual in charge. After Roger Revelle, still a Navy commander in the Bureau of Ships, convinced the Navy of the merits of the plan, he then had to convince the equally reticent University of California of the same merits of essentially "indefinite funding" for a university entity to support the ocean science needs of the Navy. Eckart spent his next several years guiding MPL, then, when asked to take on additional responsibility as head of Scripps Institution of Oceanography (SIO), he moved MPL under the direct management of SIO.[68]

Succeeding Eckart in 1950 at the Scripps helm was Roger Revelle, who after leading Navy oceanographic efforts while in uniform during World War II returned to his earlier career as a Scripps oceanographer. While McLean was strategizing the future of an ASW lab in San Diego, Revelle was doing the same, in the same city, for a new campus of the University of California.[69]

Substantially impacting McLean's thought processes was the fact the fleet—numerous submarines and a formidable surface force a twenty-minute drive away at the Naval Station—provided platforms to get promising ASW and pro-submarine technology to sea. According to a magazine celebrating the Navy's submarine force reaching its centennial of service in San Diego in 2014:

> Immediately after World War II, the Navy established Submarine Group San Diego to help manage the rebasing of submarines from forward locations to permanent homeports along the West Coast… In 1949, the Navy named a flotilla commander for submarines in San Diego, the first submarine flotilla organized since World War I, and recognition that San Diego was to become a major hub for submarine operations in the years to come... Within the flotilla,

---

[68] Fred Speiss and William Kuperman, "The Marine Physical Laboratory at Scripps," *Oceanography*, Volume 16, Number 3, 2003.

[69] In 1954 Revelle wrote a statement on educational policy relative to the UC system generally regarded as the opening shot in the fairly lengthy and difficult but ultimately successful battle to establish a major campus in San Diego. UC President Clark Kerr in a 1965 letter clearly acknowledged that: "It was you more than any other person who visualized the development of San Diego as a general campus and it was your leadership that was instrumental in developing plans for the large and distinguished educational facilities that would be required by a growing San Diego…" When the university became a reality, Revelle was selected dean of the School of Sciences and Engineering and chief administrative officer. Incredibly, and to the shocked dismay of the community, the UC regents did not select him as the first UCSD chancellor, but rather Dr. Herbert York, the same Dr. York whom President Eisenhower had named the first Director of Defense Research and Engineering only a few years earlier.

> Submarine squadrons THREE and FIVE were based aboard submarine tenders *Nereus* (AS-17) and *Sperry* (AS-12), each with fifteen submarines…[70]

As the Navy migrated to nuclear power for submarines, San Diego Congressman Bob Wilson launched a concerted effort to bring some of them to his city. He pushed for a base on Point Loma, with community (and Navy) support:

> With momentum building for a submarine base at Ballast Point, but to avoid delays associated with officially designating a new 'base,' the Navy subtly titled all Fort Rosecrans property as simply an extension of the preexisting U.S. Navy Electronics Laboratory on 1 March 1959.[71]

Interestingly, the NOTS Central Staff report documenting plans for the ASW base included information on a background literature review, some of which was at absolute odds with the centralization philosophy emerging at the highest levels of DoD at the time: "Decentralization is more effective and more productive"[72] and "However, top management needs to be encouraged to think rather of the power it can relinquish than of how much it can retain in its own hand."[73]

ASN champions lab at air station

In the midst of his deliberations about the Navy's bilinear structure and establishment of a Director of Navy Laboratories position, Assistant Secretary of the Navy (R&D) Dr. Robert W. Morse sent a memo to the Chief of Naval Material June 14, 1965, expressing frustration with the long-simmering issue of Pasadena inadequacies. His opening statement describes the issue: "For many years there has been an urgent need to replace the outmoded facilities of the Pasadena Annex of NOTS, but debate about the location of new facilities has dragged on."[74]

---

[70] Captain Bruce Linder, USN (Ret.) and Captain Sam Ward, USN (Ret.), "Ballast Point: A Premier Base for Submarines," *Mains'l Haul, A Journal of Pacific Maritime History*, Vol. 50, 3 & 4, Summer/Fall 2014, 10-11.

[71] James W. Hinds, *San Diego's Military Sites* (San Diego: San Diego Historical Society, 1986), 110.

[72] Peter Drucker, *The Practice of Management: A Study of the Most Important Function in American Society* (New York: Harper & Row, 1954).

[73] Professor George A. Smith, Jr., *Managing Geographically Decentralized Companies* (Boston: Harvard University, Graduate School of Business Administration, Division of Research, 1958).

[74] *Review of Navy R&D Management*, 402.

He described some of the studies and recommendations cited above. He then advised the Pasadena preference to remain on Foothill Boulevard was pulled from the FY1966 Military Construction (MILCON) bill "without prejudice" because the need to improve the Navy's ASW posture required planning for "a very broad range of future possibilities," an impossibility at the current site. He advocated a spacious site at Naval Air Station (NAS) Los Alamitos, in south Los Angeles County, for an expanded ASW facility. In a friendly fashion ("Will you please take the following actions…?"), he directed the Chief of Naval Material to ensure construction specifications for the Los Alamitos lab appeared in the FY1967 MILCON program submission and to reserve the proposed air station site for this purpose. He further directed initiation of planning for the lab's future role in ASW.

In response, the CNM, Admiral I.J. Galantin, delegated one of his senior officers, Captain Barney Towle, to gather key personnel from appropriate Navy commands, including Douglas Wilcox of NOTS Pasadena and Dr. Donald Wilson of the NEL in San Diego, to comply with the ASN's direction.[75] The selected group met with Dr. Morse July 8, 1965 to discuss his intentions for the planned lab, and subsequently prepared a report on "Initial Planning for Establishment of an Undersea Warfare Laboratory on the West Coast," dated 30 July. Wilcox and Wilson were tasked with preparing the draft of the proposed mission, objective, and functions of the lab. The mission as stated was: "To conduct a program of RDT&E and Engineering Support in undersea warfare and technology."

In an interesting comment on the times, the report notes disagreement of the majority of participants with the OPNAV representative, who favored emphasizing air-focused ASW systems in the mission to back up the Naval Air Development Center. The dissenters proposed another approach, suggesting:

> This course has the advantage of meeting the project manager's need without lending an appearance of excessive functional duplication. Recent experience indicated that the appearance of such duplication may in the present atmosphere invite higher echelon criticism. The resultant defensive reviews waste much time and produce extensive damage to local morale.[76]

---

[75] Towle was a CNM staff member and later Deputy Director of Navy Laboratories. His final assignment in uniform was as Commander of the Naval Air Development Center. When he retired, he was hired as a civilian at the Naval Undersea Center in 1969. He was executive secretary of the six-person team that oversaw the merger of NUC and NELC into the Naval Ocean Systems Center in 1977. With its establishment, he continued in his previous NUC position as Air Systems Program Manager. He retired January 1, 1987 with forty-five years combined military and civilian service.

[76] "Initial Planning for Establishment of an Undersea Warfare Laboratory on the West

Upon his arrival back in Pasadena after the meeting, and before the report was issued, Doug Wilcox dutifully sent a memo to the NOTS commander, advising about the meeting and providing the "second draft" of the proposed areas of interest to be assigned the new lab,[77] which included assignment of NEL's ASW work. At the end of the memo, in a unique "P.S.," he highlighted concerns that might require the station commander's attention, such as: ensuring the lab remained "attached to China Lake," maintaining the Pasadena Lab intact and in control of its needed support functions, and maintaining a "broad mission ('cradle to grave')." A key concern, although he did not state it as such in the memo, was the potential for the new lab to fall under the authority of the naval air station.[78]

Lab planning progresses to MILCON submission

The new submission for the FY67 MILCON requested by ASN Morse replaced the earlier plan of a six-story building in Pasadena with two two-story buildings and a one-story lab and shop building, plus a training classroom building and cafeteria. All these were to be sited in a large open area on the northwest corner of the air station. Subsequently, the "Pasadena technical director" (almost certainly Doug Wilcox) and the Public Works Officer emphasized the first increment of the construction project, totaling 275,000 square feet, would handle only the current Pasadena workforce and could not cover any expansion. That, perhaps, was intended as a reminder the ASN directive had stated specifically the new facility, wherever it was, had to be larger than was possible on Foothill Boulevard.

Coast (Interim Report)" to Assistant Secretary of the Navy for Research and Development, 30 July 1965,

[77] Head, Underwater Ordnance Department memo to NOTS Commander, Subj: "Report of Meeting of Study Group on West Coast ASW Laboratory," 12 July 1965.

[78] In Deputy DDR&E Chalmers Sherwin's "A Plan for the Operation and Management of the Principal DOD In-House Laboratories," dated November 16, 1964, there is a "Freedom from Tenancy Status" clause: "Task 97 studies have shown that laboratories which are tenants on a large military installation usually have many handicaps. In the new organization [of DoD labs], therefore, laboratory locations which do not have this handicap will be favored wherever possible, and any new laboratories will be planned to meet this important requirement." As will be discussed in Volume II, remarkably similar Navy actions in the 1990s, termed "regionalization," produced not merely handicaps but disasters for the Navy laboratories.

In an August 1965 letter, the Bureau of Naval Weapons (successor to the Bureau of Ordnance in 1959) advised the sister Bureau of Yards and Docks that the FY67 MILCON had been submitted through the review chain, but an additional requirement had to be addressed.[79] It stemmed from representatives of the Office of the Chief of Naval Operations (OPNAV) and the Anti-Submarine Warfare Systems (ASWS) project, who advised systems engineering and in-house capability for engineering service to ASW fleet units would be included in the new lab's assigned responsibilities. In planning for this requirement, Captain Towle's group had agreed increasing the Pasadena staff of 780 to 1,000 would reasonably allow undertaking the systems management function and expansion of fleet engineering support. Dubbed the "second increment," it involved another 63,000 square feet of required space with very similar facilities to the first increment.

Estimates of occupancy dates of the new facilities were mid-1968 to early 1969 (assuming the MILCON request was approved), with the second increment a year later and much more likely to slip. Notified of that, the OPNAV and ASWS reps stated clearly delay in establishing systems capability and expansion of engineering support was unacceptable. As a result, although those two capabilities were intended for the second increment, it was agreed to include them in the first, with the increase of Pasadena personnel intended to handle the additional workload. (A "profile" of the Pasadena facilities at the time listed 823 civilian personnel, most assigned to the Foothill location, 33 at Morris Dam, 2 at Seal Beach, 28 at Long Beach, and 73 at San Clemente Island. Long Beach and SCI also had substantially more than a hundred military.)

Foothill Freeway

In the midst of this complicated preparation for establishment of a new lab, a closer-to-home and more pressing concern surfaced at Pasadena as planning moved ahead for the Foothill Freeway, Interstate 210. In the "path of destruction" it cut through central LA County, it would take out the southwest corner of NOTS Pasadena's property. In October 1965, the NOTS commander notified the Bureau of Yards and Docks the relocation plan of the State of California (move out of the building, knock it down, and *then* build a new one elsewhere) was not feasible. His

[79] Chief of Bureau of Naval Weapons letter of 5 August 1965 to Chief, Bureau of Yards and Docks.

rationale was the machine shop in that building was required for essential project work critical to the operational Navy. The specified delay for destruction and construction was not an option. Ultimately, the state funded construction of a new building while machinists toiled on in the old one, and their machines were moved in a short period to the new facility, after which the one in the freeway's path was knocked down. Interestingly, the replacement machine shop went into service only a few months before the announcement of Pasadena Lab closure.[80]

Emerging requirements kept Pasadena management on the move, with Doug Wilcox and Officer-in-Charge Captain Grady Lowe driving to Los Angeles International Airport for a late-night meeting with Dr. William P. Raney, one of Navy Assistant Secretary Morse's key advisers. In post-meeting notes, they advised he "had an agenda," although opening conversation appeared to be primarily "NOTS management attitudes and actions on the new laboratory."[81] One significant agreement was that NOTS should be granted the equivalent of a "deed" to the land at Los Alamitos, "clearly separating this territory from NAS," which Dr. Raney said he would work.

The "agenda" was that Dr. Garwin of the President's Science Advisory Committee had reported to the Secretary of Defense the Navy was not moving ahead appropriately with the ASW "master lab" plan. McNamara bumped the letter to Secretary of the Navy Paul Nitze and his assistant for research Robert Morse; SecNav cited the "new NOTS laboratory" as evidence to the contrary. The Navy response advised the service was "now fully and openly committed to the new lab MILCON project as a matter of first priority Navy policy and prestige." In their notes, Wilcox and Captain Lowe also anticipated an increased functional scope for the new lab, including the possibility of directing work at other Navy labs on ASW systems integration for ships and aircraft.

Ocean science and engineering roles proposed

Not mentioned in the meeting notes for the airport discussion, but already formally stated in Captain Towle's report to ASN several months earlier, was an

---

[80] Naval Undersea Center *Seascope*, December 8, 1972 and April 27, 1973.

[81] "Discussions with Dr. William P. Raney, Special Assistant – ASN (R&D), 16 November 1965," signed by both and suggestive of a "memo to file."

additional assignment that would provide project work for decades for the Pasadena organization, nearly rivaling the ASW work: "To assume, under the direction of Director, Special Projects, assigned undersea warfare RDT&E such as deep submergence technologies, recovery, and underwater instrumentation, underwater launcher development and missile underwater flight characteristics."[82]

Assignment of these major new responsibilities was not a surprise to the project personnel at NOTS Pasadena; they had been involved along those lines for several years, on work that was an outgrowth of the principal Polaris missile study. It may be remembered from the previous chapter that the Nobska Study in 1956 affirmed the NOTS recommendations on Polaris. The study, as was noted there, also included a much-wider range of deliberations:

> Project Nobska… was also a boon to the study of oceanography. The Nobska panelists included not only military and civilian Navy experts but also such noted oceanographers as Columbus O'Donnell Iselin, Carl Eckart, and Roger Revelle. According to Dr. Gary E. Weir, historian for the National Geospatial Intelligence Agency: 'Oceanography came of age with Nobska… the CNO himself had publicly sanctioned oceanography as the most comprehensive way of effectively appreciating the Navy's natural medium.'[83]

Pasadena personnel had pursued areas of interest ("deep submergence technologies, recovery…") that would shortly assume pressing importance.

Thresher loss stimulates action

As detailed in Chapter 8, the Special Projects Office was a 1955 invention of Secretary of the Navy Paul Nitze that bypassed the current bureau structure for management leadership in order to develop a Navy strategic missile. The office led development of the Polaris submarine-launched missile, and at this time (mid-1960s) was heavily involved in the follow-on missile, Poseidon.

Although the office had a fairly full plate of responsibilities, a disastrous ship loss forced SPO into another area of endeavor: On the morning of April 10, 1963, the Navy's newest nuclear submarine dove to a depth of 1,000 feet in the Atlantic, 220 miles east of Cape Cod. USS *Thresher* (SSN-593) was performing sea trials

---

[82] "Initial Planning for Establishment of an Undersea Warfare Laboratory on the West Coast (Interim Report)," Appendix 2.
[83] Cliff Lawson, *The Station Comes of Age*, 475.

with a crew of 108 officers and men, plus four non-crew officers and seventeen civilians on board for the trials. At 09:13, her escort, the submarine rescue ship USS *Skylark* (ASR-20), received the message, "Experiencing minor difficulty.... Have positive angle.... Attempting to blow.... Will keep you informed." Three minutes later, *Skylark* received a garbled message from *Thresher*, recorded in the ship's log as a cryptic "900 N." Then, silence.[84]

Thresher was lost with all hands. With little information other than the garbled message, the cause of the disaster was unknown, and the Navy launched an immediate and urgent investigation. Clearly, the best evidence could be found in the sub's wreckage, but that lay 8,400 feet underwater, far too deep for any Navy asset to reach, with the sole exception of the Navy Electronics Laboratory's bathyscaph *Trieste*. As detailed in the previous chapter, *Trieste* departed San Diego less than a week later, and subsequently located and provided positive identification of the debris field that was the only remnant of a state-of-the-art nuclear submarine and 129 human souls. That debris field resulted from a pressure-hull implosion between the depths of 1,300 and 2,000 feet. The cause was eventually determined to be a chain of mechanical failures and unforeseen hazards that flooded *Thresher*'s rear compartments, causing her to sink to implosion depth.[85]

Nearly as wrenching as the loss of the submarine and her crew was the next thought: if *Thresher* had "bottomed out" at a non-crush depth of 500-1000 feet, the crew still would have perished, since there was no feasible way to rescue them, according to Center ocean engineer Norm Estabrook:

> When the *Thresher* went down in about 1963 or so—I can't remember the exact date [It was in fact April 10, 1963, precisely two days after Estabrook started work at the NOTS lab in Pasadena as a Junior Professional]—it was a real wake-up call, because the Navy realized that if the *Thresher* had gone down in 200 feet, or 300 feet, or even 500 feet, it would have been way shallower than its hull crush depth. As a result, you'd have 130 sailors sitting there on the bottom, and we had no capability to do anything for them. Nothing. We couldn't go down there with divers. The McCann chambers wouldn't go that deep. Nothing. And that was a very sobering thought to the submarine Navy.[86]

[84] Bruce Rule and Norman Polmar, "50 Years Later, a Look at What Really Sank the Thresher," *Navy Times*, April 4, 2013.
[85] Rule and Polmar.
[86] Norm Estabrook China Lake oral history interview by Leroy Doig III, 9 August 2011, 7-8.

Sobering thoughts often lead to positive action, which in this case was the formation of a new Navy office to lead efforts on a combination of two requirements: the development of a practical craft to rescue stranded submariners and a formal program of Navy-sponsored oceanographic study. The resultant organization was the Deep Submergence Systems Project (DSSP).

Levering Smith "spins off" DSSP

The Special Projects Office (SPO), established for the express purpose of putting Navy ballistic missiles to sea, was headed at the time by one of its very first recruits, former China Lake technical officer Levering Smith. Now possessing the flag rank considered impossible, or at least improbable, for an engineering duty officer, he deliberated where to position the newly established DSSP in the hierarchy of his organization. After due consideration, he determined it best to imitate Navy Secretary Nitze and spin it off as a separate office (which Nitze had done with SPO). He selected his chief scientist, Dr. John Craven, to manage it. In September 1966, DSSP's main office was established on Point Loma in San Diego, half a mile from NEL's waterfront area, at the Submarine Support Facility, Ballast Point.[87] Although NEL was still involved substantially in undersea and ocean-related work, (an outstanding example of which is the *Trieste* exploration of the *Thresher* debris field detailed above), DSSP went to NOTS Pasadena as its primary source for test equipment and a test range. Stimulus for the latter, which included major construction planned at San Clemente Island for a DSSP testing complex, resulted for pro-active marketing by Howard Talkington and Ivor Lemaire, which will be discussed in Chapter 12.

At the time of its inception, according to Volume 4 of the NOTS history, "DSSP was well funded, but initially unfocused."[88] To gain focus, Don Moore's group at China Lake was tasked to provide a formal plan for oceanographic work of interest and importance to the Navy. This was consistent with DoD directives published in March 1960 and June 1962, requiring annual "Technical Development Plans" for each RDT&E project, to include the requirements establishing the project, a schedule of development milestones, and a financial

---

[87] NEL *Calendar*, May 21, 1965, 2-3.
[88] *The Station Comes of Age*, 518.

plan.[89] According to Moore, "a very healthy development program in that area" was recommended, resulting in "a sales pitch basically to try to get all of the 22 Navy laboratories plus the captive laboratories together to do a plan…"[90] Moore gave presentations at each organization, including the Pasadena Lab, "and then George Wilkins and Howie Wilcox really finished up the creation of the plan."

Coincident with these presentations, the Navy reorganized its West Coast laboratory structure, which is discussed immediately below. In the meantime, the DSSP development plan moved forward during the reorganizing, as Bill McLean gathered resources from his new organization to complete that plan.

At the time, Howard Wilcox, disillusioned with the high-level politics in Washington and with the Detroit auto industry, was managing a consulting firm in Santa Barbara. He was contracted by McLean to support the handful of people leading development of the Technical Development Plan (TDP): Wilkins, employed at China Lake, but beginning his transition to the newly established Naval Undersea Warfare Center managed by McLean; George Anderson, who was transferred from the Point Loma electronics lab to McLean's new organization; Ivor Lemaire of the Pasadena Lab; and Robert Breckenridge of the Naval Civil Engineering Laboratory at Port Hueneme. In a letter to McLean in the spring of 1968, Wilcox highlighted the contributions of each to the effort, and emphasized support provided by a fair number of others, citing several by name.[91]

Norm Estabrook, who would work for and later succeed Ivor Lemaire as head of the Point Loma lab's ocean engineering division, observed:

> …they had outlined a number of what they called 'demonstration projects'… [as an unrelated example] sending a man to the moon was a demonstration project. It had a high-minded ideal… but if you stood back and looked at that objective, you'd say, 'That doesn't make any sense.'

It was certainly true, that merely placing a man on the moon offered no particularly important benefit. Or, as Estabrook asked, "What is he supposed to do?" However, "In order to do it [put man on the moon], you had to develop transistors, you had to develop rocket motors, you had to develop life-support systems,… And those were the valuable products, the outgrowths of a demonstration project."[92]

---

[89] *Review of Navy R&D Management*, 211-12.
[90] Don Moore interview conducted by Elizabeth Babcock, October 11, 1990, 43.
[91] Dr. Howard A. Wilcox letter to Dr. W.B. McLean, 9 April 1968.
[92] Norm Estabrook SSC Pacific oral history interview conducted by Tom LaPuzza, January

Four-level development plan

The multi-tiered final plan presented to the sponsors featured a set of major demonstrations at the top level; "the next level described the components needed for each project; the third level specified the subsystems necessary for those components; and the bottom level described the technologies that would have to be developed to create those subsystems."[93]

Lemaire recalled decades later that Don Moore and his associates had gathered "gobs and gobs and gobs of technical information" but failed in the effort "to squeeze [it] into this TDP format."[94] The TDP, he said, is "like a summary of a program… sort of a funding document that describes what you're doing and why you're doing it." He acknowledged the efforts of Moore and others to accumulate information necessary for the plan, but forcing that into the required template demanded by DoD was "a nightmare." Given his interests and capabilities in those areas, Lemaire, with assistance from a local contractor who supported a number of projects at the Pasadena Lab, was able to "get the thing to the point where it was acceptable to Washington."

The completed effort was formally titled the Deep Ocean Technology Technical Development Plan. According to Moore,

> … that program was funded, oh, $10 to $20 million a year for years. A lot of different stuff came out of it. The Hawaii Lab lived off of that program, lots of people here in San Diego lived off of it, lots of people at Woods Hole [Oceanographic Institution], and NSRDC [Naval Ship Research and Development Center], and DTRC [David Taylor Research Center]… The way the program was written originally, we had two or three focal projects that we thought would serve as an umbrella to force the development of technology.[95]

In an issue of *Astronautics and Aeronautics* magazine, essentially dedicated to the undersea warfare center, George Anderson, who headed the NUWC Ocean Sciences Department as well as serving as a principal in the TDP group, explained the general goals of the program, basically equipping the future Navy with deep-ocean technology necessary to respond "quickly and efficiently to whatever new operational needs may arise" and sharing those technologies with the private

---

5, 2012, 5-6.

[93] *The Station Comes of Age*, 518. Wilkins is quoted in that citation as saying the sponsors "were overwhelmed, praised everything we had done, and promised future funding."

[94] Ivor Lemaire oral history interview conducted by Tom LaPuzza, April 16, 2019, 18-19.

[95] Don Moore interview, 43-44.

sector. He went on to elaborate on the focus areas:

> The DOT [Deep Ocean Technology] focal projects, as presently planned, foresee—
>
> 1. An interim transportable mobile undersea station (6000 ft).
> 2. A continental-shelf manned bottom installation (850-1000 ft).
> 3. A surface-stabilized support platform (6000 ft).
> 4. An interim work submersible (8000 ft).
> 5. A transportable (mobile) undersea station (12,000-20,000 ft).
> 6. A manned bottom (in and on the sea floor) installation complex.[96]

In addition to Anderson's article, the issue featured a question-and-answer of Dr. Bill McLean by the magazine's editor-in-chief on ocean engineering, and articles by Anderson's associates Will Forman, Ronald E. Jones, and Hudson Hascall. Dr. John Craven, chief scientist for both the Deep Submergence Systems Project and Polaris, contributed "Ocean Technology and Submarine Warfare."

Information sharing sessions

In an early instance of cooperative effort between the weapons and electronics laboratories, an information exchange session was held in San Diego on June 6, 1966, at which NOTS personnel provided a detailed briefing on their DSSP work to employees of the Navy Electronics Laboratory. It was the third such session. On April 1, the first "seminar in the program" was held in San Diego, when NEL personnel briefed NOTS engineers on their planned project work with the USS *Dolphin* (AGSS-555). At the time, NEL was establishing its Dolphin Research Sonar Project Office and developing an in-depth plan for operations when the submarine went to sea in a couple of years. It was perfect for the information exchange, because the following year the submarine project office and its staff would be transferred from NEL to the NOTS' successor Naval Undersea Warfare Center. (At the second session, NOTS engineers discussed the Sonaray project.[97])

---

[96] "Ocean Engineering: The Next Generation," *Astronautics and Aeronautics*, April 1969, 46.

[97] "NOTS and NEL share knowledge," Navy Electronics Laboratory Command History, 1965-1967, 7.

Weapons development and ocean engineering

Meanwhile, back to the effort to replace inadequate Pasadena facilities: the Underwater Warfare Laboratory (UWL) complex planned at Los Alamitos was shaping up to be not only a major weapons development entity, but also one heavily involved in ocean engineering. Planning for this was noted in a 9 August 1966 letter from the Southwest Division of the Naval Facilities Engineering Command (the successor to the Bureau of Yards and Docks) to the Pasadena officer-in-charge, advising a master plan had been prepared and forwarded to him for the "Naval Oceanographic Research and Underseas [sic] Systems Laboratory." The letter advised this lab would be sited south of the air station runway, whereas the weapons lab was in the northwest corner of the property. When the blueprints arrived, they called for two two-story lab and office buildings, a one-story machine shop building, and a cafeteria. It looked remarkably (but not identically) like the UWL plans, and was marked "second increment." The letter went on to suggest if the allotted site didn't work, this facility could be co-located with the UWL, but that would require "multi-story structures." (The committee formed by Captain Towle at the direction of ASN Morse had already overruled the concept of the six-story building in Pasadena.)

Unfortunately, Congress declined to include funds for either of the proposed laboratories in the 1967 MILCON.[98] Undeterred, planners advanced similar proposals for the FY68 MILCON. NOTS assembled a presentation (extant copies are undated) titled "Military Construction Presentation for Naval Ocean Technology Station," thus cleverly projecting the NOTS acronym to the proposed facility. The location was still Los Alamitos, but the proposal was now for a single venue, price tag $8.5 million, to "provide a 1000-man laboratory focused toward increased effort both in USW [undersea warfare] weapons systems and ocean technology" and "for focusing Navy activities and support of the national ocean technology program."

The presentation included San Clemente Island, citing work there for Polaris and SUBROC (Submarine Rocket, an underwater version of ASROC) and

[98] The NOTS Commander letter to Commanding Officer, NAS Los Alamitos, dated 11 March 1966, thanked him for providing information on potential support services available from the air station and advised the Department of Defense had deleted the laboratory from the FY67 budget review. The deletion occurred as DoD drastically cut funding in other areas to pay the hefty bills for the Vietnam War, heating up at the time.

planned support for the Polaris follow-on Poseidon. Also included were plans for anticipated DSSP support. The final graphic touted the greater value in expanding to a "2000-man lab," and "encouraging development of a 'Government-University-Industry Park' adjoining the Navy laboratory." Planners evidently were seeking a major "military-industrial complex" (not exactly the Eisenhower version), recognizing previous and ongoing highly productive associations with California Institute of Technology and the University of California.

"Centers of Excellence"

While the Navy R&D community struggled to move from the century-old bureaus to the systems commands, and the local West Coast Navy R&D community was developing a laboratory complex at NAS Los Alamitos, Dr. John Foster ordered yet another study. Foster, who had succeeded Herbert York and Harold Brown as Director of Defense Research and Engineering, sought an evaluation of the Defense Department's in-house laboratories. In response, the Defense Science Board recommended reorganizing them into weapons centers, each assigned a specific (presumably narrow) warfare area of concentration.

Foster directed the Navy to prepare for establishment of those weapons systems development centers, three on each coast, an action which would have substantial impact on the two labs discussed in this volume. Based on an otherwise unrelated federal program to fund universities to perform government R&D, the term "Centers of Excellence" was applied to these proposed Navy organizations.

The Naval Ordnance Test Station, tasked with weapon development but consistently "branching out" into other technology areas as the seeds of creativity sprouted, was opposed to limitations on that creativity. As an intriguing example, Robert M. Hillyer, technical director both of the NOTS-successor Naval Weapons Center at China Lake and the Naval Ocean Systems Center on Point Loma, with service as the Director of Navy Laboratories in between, cited the China Lake development of swimmer delivery vehicles for Navy Special Forces, a project that was reasonably much more suitable for a Navy located near the ocean.[99]

[99] Robert M. Hillyer SSC Pacific oral history interview conducted by Tom LaPuzza, August 21, 2013, 9.

A recommendation from a NOTS Advisory Board meeting advised against a policy to establish rigid boundaries for laboratory work areas:

> With constantly changing environmental conditions, and constantly developing new technologies, it would appear not in the best interests of the Navy to implement any general organization scheme which might involve such strict compartmentalization that certain warfare areas were assigned exclusively to specific laboratories.[100]

It went on to emphasize the desirability of "flexibility of operation and program diversity in many overlapping warfare areas."

Despite that seemingly reasonable argument, Dr. Robert Frosch, who was named Assistant Secretary of the Navy (R&D) in 1966, made it clear the Navy would move forward with Dr. Foster's plan. (A note from a NOTS management meeting at the time stated, "All laboratories are opposed to that approach, but they have not been able to change it.") With perseverance reminiscent of its technical project work, NOTS teamed with the Navy Electronics Laboratory in San Diego and the Naval Ordnance Laboratory in Corona, California, to suggest a different, probably unrealistic, approach: the trio would form a conglomerate titled "Naval Warfare Center, Pacific."[101] That proposal also went nowhere.

In the spring of 1967, the *Rocketeer* ran a brief article about the Navy plan, terming it a "proposal," but in self-contradiction providing an implementation date.[102] The article also reported in a couple of sentences on the new "U.S. Naval Undersea Warfare Center, Pasadena," including the statement, "Current plans to re-locate NOTS Pasadena to Los Alamitos remain unchanged." NEL's *Calendar* didn't mention it until it published one run-on sentence in a box in its June 30 issue announcing, "New Laboratory Centers Announced."

Three Navy Centers established

On June 30, a Department of Defense press release made it official, that the Navy was initiating a major reorganization involving several California-based

---

[100] NOTS Advisory Board meeting November 3-4, 1966, Recommendations, 1, cited in *The Station Comes of Age*, 639.
[101] *The Station Comes of Age*, 641.
[102] NOTS *Rocketeer*, 14 April 1967, 3.

laboratories:

> The three new centers are: The Naval Command Control Communications Laboratory Center (NCCCLC), San Diego California, to be created from the present Navy Electronics Laboratory (NEL), San Diego (less its Underseas Technology Directorate); the Naval Undersea Warfare Center (NUWC), Pasadena, California, made up of the Pasadena Annex of the Naval Ordnance Test Station (NOTS), China Lake, and the Underseas Technology Directorate of NEL, San Diego (no facility moves anticipated; the several auxiliary sites of NOTS Pasadena Annex will also become part of the Naval Undersea Warfare Center); the Naval Weapons Center (NWC), China Lake, established from NOTS China Lake, and the Naval Ordnance Laboratory (NOL), Corona, California.[103]

The "new" laboratory, headquartered in Pasadena, would be headed by the (former) NOTS Technical Director Dr. William B. McLean (at first as acting TD) and Captain Grady Lowe, who was at the time the Pasadena officer-in-charge. Captain Lowe would in fact be the commander of both the China Lake and Pasadena centers for several months. Dr. McLean's China Lake deputy, Haskell G. Wilson, would be the acting TD there. Captain William R. Boehm and Dr. Ralph Christensen would continue in their leadership roles on Point Loma, although Captain Boehm's title of Commanding Officer and Director would be changed to Commander of NCCCLC.

The first issue of *Rocketeer* after the reorganization, speaking for its now former Pasadena organization augmented by a piece of the former NEL, stated, "The Naval Undersea Warfare Center will conduct a program of warfare analysis, research, development, test, evaluation, system integration and fleet engineering support in undersea warfare and ocean technology."

With nearly identical words, the former NOTS-now NWC at China Lake was charged with conducting "a program of warfare analysis, research, development, test, evaluation, systems integration and fleet engineering support in naval weapons systems principally air warfare…" Echoing that philosophy about avoiding restrictive mission assignments, someone (the editor, perhaps?) added, "…and will conduct investigations in related fields of science and technology."[104]

---

[103] News release from the Office of Assistant Secretary of Defense (Public Affairs), June 30, 1967, quoted in Congressional Record: Hearings Before the Special Subcommittee on Proposed Undersea Warfare Laboratory, Los Alamitos, Calif., 4035.
[104] Naval Weapons Center *Rocketeer*, July 7, 1967, 1.

The statement continued,

> The regrouping of selected Navy laboratories into 'centers of excellence' is expected to strengthen their capability for systems development management. Each center is to develop a substantial systems analysis capability in order to maintain balanced perspective, to assess relative merits of alternative developments, and to provide sound program planning. The centers will join in interpreting intelligence estimates as a guide to planning and programming. The centers will maintain contacts with the fleet and fleet problems, so that they have current knowledge of operating forces, capabilities, limitations and goals…"

On Point Loma in San Diego, NEL's fairly straightforward title was swapped for the difficult Naval Command Control Communications Laboratory Center, occasionally written with a comma between "Command" and "Control." Within a couple of weeks, however, a front-page *Calendar* article announced, "Laboratory Name Redesignated NELC" and advised an NELC notice (perhaps suggesting the organization took the name-change action itself) directed the new title of the lab would be the Naval Electronics Laboratory Center for Command Control and Communications, shortened to NELC.[105]

The previous issue of the *Calendar* (July 14) had introduced the "center of excellence" term, lower-cased, citing informally the planned areas of emphasis as "the fields of radio, radar, digital data links, satellite communications, electronic warfare, tactical and strategic data systems, and electronic displays." The July 21 issue provided the formal mission: "To conduct a program of warfare analysis, research, development, test, evaluation, systems integration and fleet engineering support in command control and communications technology."

Congressional interest

Somewhat concurrently with the Navy reorganization, but with no relationship to it whatsoever, one of those anomalies of complexity, confusion, and poor timing occurred when "someone" added a line item to the proposed congressional military spending bill in late spring 1967. That item funded the Undersea Warfare Laboratory at NAS Los Alamitos to the tune of $8.45 million, with a second, identical amount to be requested in the following year's MILCON. Congressman L. Mendell Rivers (D-SC), surprised to see that item since he could

[105] NELC *Calendar*, July 21, 1967, 1.

not recall being briefed about it, made inquiries through intermediaries to the appropriate Navy flag officer, Vice Admiral Charles B. Martell. The director of ASW programs for the Chief of Naval Operations reportedly was also surprised. The powerful chair of the House Armed Services Committee immediately ordered an investigation, empowering a Special Subcommittee on Proposed Undersea Warfare Laboratory Los Alamitos, Calif. to seek answers. That subcommittee, headed by Rep. Porter Hardy (D-Va.), "invited" Assistant Secretary of the Navy (Research and Development) Dr. Robert A. Frosch to testify on the matter.[106]

Frosch brought his special assistant for research, Dr. William Raney, and Director of Navy Labs Dr. Gerald Johnson for an interesting interchange on July 12, 1967. During that hearing, ASN substantially supported the plan to move the Pasadena underwater weapons organization of 850 personnel and 450 NEL ASW researchers with their programs to Los Alamitos. Upon questioning by the subcommittee chair, Dr. Raney advised Dr. Frosch's predecessor, Dr. James H. Wakelin, had considered various sites for the new ASW lab, particularly in light of the concern about losing experienced (and essential) technical personnel. A series of questions and answers established the facts that both Seal Beach and NAS Los Alamitos had been evaluated as possible sites for the lab, and overruled by Wakelin in favor of Pasadena, specifically "on the grounds that any move at all would seriously endanger the retention of the professional personnel."[107] Dr. Frosch continued to maintain the validity of the Los Alamitos plan.

Before moving on, an important point should be made, that there were actually two actions proceeding simultaneously, somewhat related but not identical and so fairly confusing to ground truth: the congressional group was responding to a MILCON request for a *facility*, a physical plant with various buildings and also various names, costing some amount of public monies which Congress alone was empowered to approve. The Navy's action had to do with an *organization*, a certain number of people involved in certain activities in a facility or facilities with (at the time) unknown geography. Clearly the Navy could reorganize if it chose to, and mostly didn't require congressional approval to do so. On the other hand, if it wanted physical facilities for those organizations, Congress had to approve and pay for them. Subcommittee members, tasked to look into the

---

[106] Report and Hearings of the Special Subcommittee on Proposed Undersea Warfare Laboratory, Los Alamitos, Calif. of the Committee on Armed Services, House of Representatives, Ninetieth Congress, first session: July 12, 13, 21, and 22, 1967, 4036-4064.

[107] Report of Special Subcommittee, 4038-9.

funding request for a facility, became ensnared in the debate over which organization would be located where and what responsibilities it would have.

Dr. Frosch continued his lengthy testimony, expressing the value of bringing Navy scientists and engineers from Pasadena and San Diego to a facility he wanted Congress to fund at NAS Los Alamitos. Truth be told, he (or at least the Secretary of the Navy) had already merged those two organizations into the Naval Undersea Warfare Center about two weeks earlier. What he sought now was an appropriate facility where he could house them and task them with improving the Navy's ASW stance. He maintained the critical Navy mission of "undersea warfare has been too fractionated and the work too divided up among a number of laboratories and installations" for years, and studies both inside and outside the Navy had recommended consolidation of the effort. Hence the plan to establish the laboratory at Los Alamitos.

Unless one was the ASN (R&D), the hearings were entertaining and not without humor, as Congressman Hardy expressed to the Navy officials his frustration. Addressing Dr. Frosch, he said,

> Well, Doctor, I have listened to this [your testimony on Los Alamitos] with a great deal of interest, because I have been listening to the Navy's reorganizations ever since I have been in Congress, and the more I hear of them the more confused I get, and sometimes I think the more confused the Navy gets... I am not a bit sure that the most recent one they did, when they changed all the names of the bureaus [to systems commands] wasn't a step backward... you have taken air and ordnance and combined it and separated it and recombined it until I don't know what you have over there right now... honestly, some of the organizational rearrangements that the Navy has been through in these last 15 or 20 years that I have been familiar with make me a little suspicious of every new organization you come up with.[108]

Also in the humorous category, Dr. Frosch stated there was insufficient pier space to tie up the planned undersea laboratory's ships in San Diego, to which Congressman Hardy rejoined, "Where are you tying up your ships in Pasadena?" Dr. Frosch deserves credit for providing a reasonable response: "Long Beach."

The subcommittee heard extensive testimony from Dr. Frosch and his associates, both on July 12 and later on July 13, after hearing from their colleagues Richard T. Hanna, Bob Wilson, and H. Allen Smith. The latter represented the congressional districts in Orange County, San Diego, and Pasadena that would be affected by the decision about placement of the Undersea Warfare Lab.

---

[108] Report of Special Subcommittee, 4060.

Congressional subcommittee visits "the scene"

The weekend of July 21-23, 1967, the subcommittee flew to California, where they made inspection tours and held formal hearings in those three locations. Anyone who has ever been in the Los Angeles area on a Friday afternoon/evening will be stunned at this itinerary and the fact it seemed to have worked: Congressman Hardy and his associates met with officials of the City of Pasadena in the afternoon, and appeared at the Pasadena Navy facility around 5:00 p.m. (with a stenographer to record) for discussions with the top officials of the new Naval Undersea Warfare Center—Captain Grady Lowe, Dr. William McLean, and Doug Wilcox. They showed up at the Naval Air Station at Los Alamitos, many busy freeway miles away, at 8:30 p.m. for a lengthy session with civic officials. Saturday morning, they arrived bright and early for a meeting with San Diego civic officials, followed by a mid-morning sit-down with the new NCCCLC commander (although the Congressional Record specifies the meeting was at the "Naval Electronics Laboratory"). Captain W.R. Boehm gave a lengthy overview of his command's facilities, programs, and accomplishments, with support from Technical Director Dr. Ralph Christensen, Chuck Manning of Naval Tactical Data System fame, and others, then answered a series of questions about technical programs and the lab situation.

Clearly from their questions the congressmen hoped to gain better understanding of what the Pasadena and San Diego labs did for the Navy (specifically the functions transferred to the new Pasadena organization), and how the planned facility at Los Alamitos would support, or improve, that. Most of Captain Boehm's presentation bore little relation to that; he discussed principally Point Loma lab projects that were not part of the consolidation with Pasadena. While the NEL/NCCCLC CO was elaborating on what his organization *did*, the lawmakers were particularly interested in what the Navy officials *thought*. At one point, Dr. Don Wilson, the Number 2 civilian at NEL on June 30 and the following day the Number 1 civilian of the new NUWC San Diego contingent, said, perhaps defensively, "Everything I say is my personal opinion." Representative Hardy jumped on that, immediately and positively: "That's what we are looking for because you've got some expert opinion and we haven't."

Hardy had sought similar opinions in Pasadena the previous evening. Bill McLean had suggested former electronics laboratory personnel who were now part of NUWC "would be much handicapped by moving to Los Alamitos because they would not be close to the water. That is where they do most of the activity that they have…"[109]

In response Hardy asked, "What you are saying is that a consolidation of Los Alamitos would be a disadvantage?" McLean confirmed that was his thinking. Hardy then suggested, "Aren't you making a case for moving to San Diego, if you move?" McLean responded, "If you would like to consolidate at the same time." At that point, Captain Lowe objected somewhat strenuously, bringing up the Morris Dam and Long Beach facilities and calling it "patently absurd to talk of consolidation." Acknowledging the reality of those specific facilities and their required locations, Hardy questioned why Pasadena and San Diego couldn't be consolidated. He also asked about communication and whether distance was the primary consideration in that; McLean admitted it was distance "and getting the people to work together as a part of a joint operation."

Later in the conversation McLean and Wilcox addressed a new location for the Pasadena Lab, ostensibly the one offered by the city and discussed with the subcommittee earlier in the day. Situated near the new Long Beach Freeway, it cut the distance from the lab to the California Institute of Technology in half. Putting that into perspective, Doug Wilcox suggested, "The best place to put the laboratory would be right next to the campus at Cal Tech."[110] The general tenor of the Pasadena participants' attitude was to stay in the city but move to a better location with space for expansion, and leave their new associates on Point Loma.

Congressman Hardy asked McLean what he didn't like about Los Alamitos. To which he responded,

> I find it personally an unattractive place to live. It is a flat area, it is down wind [sic] from the Long Beach oil operations, the housing in the immediate vicinity is not very interesting. The only places that would seem to me to be attractive would be the area along the beach and the beach front property is tremendously expensive and I am sure it would be difficult for most people to afford. Therefore, I think the recruiting problems to the Los Alamitos area would be much more difficult.[111]

It was an interesting comment from someone who had spent quite a few years at China Lake.

The next morning in San Diego the Navy officials were also asked about

[109] Report of Special Subcommittee, 4137.
[110] Report of Special Subcommittee, 4143.
[111] Report of Special Subcommittee, 4140.

moving north, about the use of Long Beach port facilities for the necessary ships rather than San Diego, and about the plan for required support for the new NUWC. (The Point Loma lab would continue to provide it for the time being to NUWC San Diego; China Lake would continue to provide it to NUWC Pasadena for now.)

"Resistance to Los Alamitos… tremendous"

Subcommittee member Donald Irwin stated, "The resistance to the possibility of moving from Pasadena to Los Alamitos was tremendous," to which Dr. Wilson suggested, "It is my proposition that the headquarters building could be at Los Alamitos, Pasadena, or San Diego with no strain on anyone." His thought appeared to be the labs and the technical personnel should remain in Pasadena and San Diego, but some subset of top management, administration, etc. could be anywhere. Irwin asked what he thought of bringing the Pasadena function to San Diego, and he responded it would be a "great disruption." Hardy dug deeper: "Then you agree with Dr. McLain's [sic] viewpoint that to undertake to move that laboratory to any reasonable distance would disrupt the personnel situation?" Wilson replied, "I certainly do… No move of any sizable group of people has ended up in anything but costing a lot of money and losing a lot of people." He provided an example from private industry and one about NOTS moving from Pasadena to China Lake that wasn't true, although that was likely ignorance of the facts rather than deception. Hardy revisited the specific question of the organization's headquarters location, and Wilson reiterated, with a qualification:

> The headquarters building can be established anywhere as I point out. And my personal opinion is it would be better at San Diego for the very simple reason that practically every command in the fleet is here in San Diego.[112]

After an interesting exchange about the difference between operations analysis people and system performance analysis people, Congressman Hardy joked, "Who currently has the capability of system analyzing this problem of locating the laboratories and the headquarters?" Wilson suggested, "… Dr. Frosch's office would say they would give this considerable thought," to which Hardy replied, "I doubt that he would and I don't think he has."

---

[112] Report of Special Subcommittee, 4182.

Subcommittee opposes relocation

With the numerous statements from those who gave testimony in hand, the congressmen discussed the issue, and agreed to recommend against the moves to Los Alamitos. Hardy penned a letter to the HASC chair:

> What the Navy was proposing by the move to Los Alamitos of the 850 from Pasadena and the 450 from San Diego was the creation of a new laboratory, the Undersea Warfare Center… the subcommittee agreed that the new laboratory should be established with the least possible interference with the present outstanding operations. Therefore the subcommittee recommends that the Pasadena laboratory be retained in Pasadena and the San Diego laboratory in San Diego. Not only did the subcommittee find that there would be little if any benefit to the two operations in being brought together physically, but it found specifically that there would be definite harm to their operation if they were moved from their present locations.[113]

Among other factors, continued access to Caltech, Scripps, and the University of California would "provide outstanding scientists for advice and consultation and for the general academic atmosphere as at Pasadena and San Diego."

The letter continued with a statement that would be disturbingly familiar to those at the lab on Point Loma who experienced the Navy's regionalization actions in the mid-1990s, that support provided by the Eleventh Naval District should be "adequate, but does not become a means of having local naval officials redeciding matters… which have had decision at appropriate R. & D. levels."

In the letter a few days later officially transmitting the subcommittee's report, Congressman Hardy summarized the proposed recommendations:

> 1. Retain the present laboratory at Pasadena, but provide it with new buildings adequate to do what is needed at that location including the purchase of the property next door... The cost should be about $10,400,000.
>
> 2. Retain the present anti-submarine warfare activities at San Diego.
>
> 3. Locate the headquarters and systems analysis group for the new Undersea Warfare Center, with jurisdiction over both the Pasadena and present San Diego operations in San Diego.[114]

Congressman Rivers convened his entire committee the next day, and the subcommittee recommendations were adopted. An interesting interchange occurred during the meeting, when Representative Charles Wilson (D-Calif.),

---

[113] Letter from subcommittee members to L. Mendel Rivers, July 28, 1967.

[114] Congressman Porter Hardy, Jr., letter to Honorable L. Mendel Rivers, Chairman, Armed Services Committee, House of Representatives, July 31, 1967.

whose 31st Congressional District was immediately east of Pasadena, asked if Congressman Hardy knew who added the budget line item that initiated all the questions and travel and testimony. His concern, of course, was the fact he and several fellow California congressmen were intensely interested in this prime opportunity for Pentagon spending in their districts. In a brief discussion during the meeting, Wilson asked if it was possible to determine who actually submitted the line item for the Los Alamitos lab to the Military Construction bill. Hardy responded candidly and completely, "It is a little difficult."

Subsequently, Recommendations 2 and 3 were duly managed by the Navy. Don Wilson had claimed the headquarters location didn't matter, but San Diego had the Navy presence. Evidence suggests the Pasadena folks (including McLean, who would continue to live at China Lake for another six months) would have constructed the headquarters building at that new proposed Pasadena location by the freeway, if it had materialized.

Despite Recommendation Number 1, the Pasadena Laboratory would close in April 1974, seven years after the congressional action and nearly a quarter of a century after the first proposals for improved facilities, having never gotten a single new building, other than the new machine shop to replace the one demolished to make way for the Foothill Freeway. That new building went into operation in December 1972, less than eighteen months before the Pasadena Lab closed.[115] (The actual closing was substantially overshadowed in news coverage by the dedication of the new Center headquarters building in San Diego and the retirement of Dr. William B. McLean.[116])

With the benefit of hindsight, it is almost inconceivable the number of studies and proposals put forward over a period of more than twenty years, without a single positive move to effect any change. It is reasonable to speculate new facilities could have been constructed at Pasadena for less funding than was spent on all the studies, solicitation of architectural-engineering bids, Congressional hearings, and resulting reports and presentations, none of which were acted upon.

It is admirable, but also characteristic, that Pasadena personnel, faced with numerous promises of new facilities that were never kept, and threatened many times with family-uprooting moves, nevertheless continued their daily efforts,

[115] Naval Undersea Center Seascope, December 8, 1972, and April 27, 1973.
[116] NUC Seascope May 17 and 31 and June 28, 1974.

producing exceptional weapons and other products, seemingly with little notice of the adverse conditions under which they labored to support the fleet.

Howie Wilcox

Howard A. Wilcox, whose Ph.D. in nuclear physics was from the University of Chicago, managed to squeeze three fairly significant careers into one lifetime: Navy weapons developer, automotive industry technology executive, and Navy environmental scientist and engineer. Along the way, he served in a high-level position in Washington and turned down a second; taught physics classes at Harvard, Radcliff, UC Berkeley and Los Angeles; managed a consulting business.

After wartime employment as a "junior scientist" on the Manhattan Project at Los Alamos Scientific Lab and service as a research assistant at Fermi Institute of Nuclear Studies, Wilcox spent a decade at the Naval Ordnance Test Station (NOTS) China Lake, first as project engineer on the Sidewinder missile and later as program manager. He managed the Weapons Development and the Research departments for two years each. Serving as NOTS Assistant Technical Director for Research when Dr. Herbert York was named first Director of Defense Research and Engineering, Wilcox was then appointed the first Deputy DDR&E.

Disappointed with the Washington assignment, he spent the next seven years in private industry, working for General Motors in research and engineering positions. Those also failed to meet his expectations: "I didn't like what I saw [in Washington], and the more I saw in industry the less I liked it there..."[117] Invited back to Washington for a return engagement as the first Director of Navy Laboratories, he turned down the offer, considering it a "window dressing type of job" with little potential for positive impact. Instead, he started his own company, offering consulting services on a wide variety of topics in which he was interested and substantially knowledgeable, including marine technology, energy systems, and military and space systems. He ran the company on a part-time basis for twenty years, with one of his clients throughout that period the National Academy

[117] DNL History Study Interview of Dr. Howard A. Wilcox by A.B. Christman, March 15, 1978, 5.

of Sciences. Apparently dissatisfied with the (lack of) time commitment, he returned full time to China Lake in 1971 to manage the Independent Research/Independent Exploratory Development programs.

Early on during his three years in the desert, he initiated the Ocean Food and Energy Farm project, the beginning of a final decade or so of Navy lab service dedicated to environmental concerns. He explained his interest and focus on that topic in the very first paragraph of a book published in 1975:

> … the next five to ten decades will confront humanity with three major challenges. First, we will be called upon to exercise great restraint in the way we use the vast natural storehouses of energy that are available to us, or else watch as our zealous consumption brings on a global heat disaster that could write an end to the history of our civilization.[118]

The second and third challenges he identified as moderate use of nuclear energy to avoid "an almost certainly intolerable sequence of radioactive threats to our whole physical and spiritual environment" and the requirement to increase food production "or else we must grow accustomed to the idea that hundreds of millions of people will die of starvation each year."

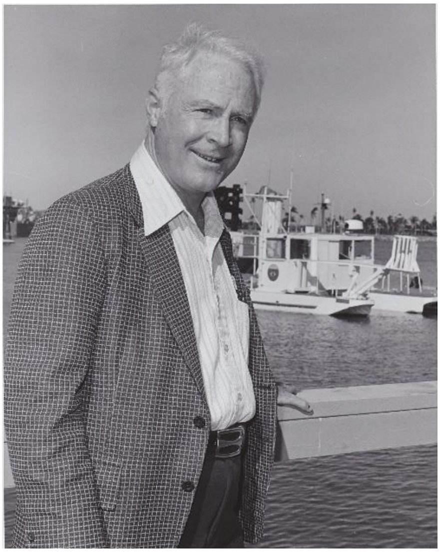
Decades ahead of the world in his thinking, as most have realized now well into the twenty-first century, he offered more than doomsday predictions: "It may seem incredible that three such awful problems could possess so simple and single an answer: to use the energy continually being received from the sun. "

He goes on to discuss the energy crisis (recall that in 1973-74 the Organization of Petroleum Exporting Countries imposed an oil embargo on the U.S., resulting in gas rationing, service station gridlock, collective and individual fear of running out of fuel), and affirms: "So yes, the use of the earth's currently received solar energy is the immediate answer to… our most immediate and pressing problems" and "can be the *ultimate, long-term answer* to our energy needs on earth."

Wilcox transferred the ocean farm project from China Lake to the Naval Undersea Center in San Diego in 1974, and received the IEEE Council on Oceanic Engineering Outstanding Technical Achievement Award for it in 1975. The award cited his major efforts in "the agricultural use of the ocean as a potential means for

---

[118] Howard A. Wilcox, *Hothouse Earth* (New York: Praeger, 1975), 3-4.



Dr. Howard A. Wilcox

meeting mankind's food and energy needs." He continued working in the Environmental Sciences Division at NUC/Naval Ocean Systems Center on Point Loma until his retirement in 1984, at which time he was presented the service's second highest honor, the Navy Superior Civilian Service Award. In that presentation, he was cited for his achievements in a multitude of technical disciplines, including aerodynamics, rocket propulsion and guidance, electronics, navigation, ocean engineering, and, as the finale of his career, solar energy.[119]

[119] The bad news is the ocean farm project "disappeared" shortly after Wilcox retired. The good news is his son, Brian Wilcox, an engineer at the Jet Propulsion Lab for 38 years and a JPL Fellow, is now (2020) principal investigator on an Advanced Research Projects Agency/Department of Energy project to "re-start the energy farm concept." Brian Wilcox email to Tom LaPuzza, August 18, 2020.

10

Technical Achievements, Organizational Changes

The decade of the 1960s, cited in the previous chapter for its many organizational and facility changes (or lack thereof), saw a significant amount of solid work accomplished by the technical personnel of the U.S. Navy Electronics Laboratory and the U.S. Naval Ordnance Test Station.[1] NEL's efforts ranged from outer space to the bottom of the sea, including fundamental scientific research of the oceans, development of communications over land and water and under the sea, and fielding emerging computer technology to satisfy the Navy's at-sea decision-making requirements. NOTS continued development of cutting-edge aircraft weapons, many of them delivered from the skies over Vietnam; improvement of submarine-launched ballistic missiles; and creation and fielding of the Navy's first underwater vehicles (manned and unmanned).

NEL projects

On September 1, 1961, NEL's *Calendar* advised the lab shortly would begin employing "mechanization procedures," including keypunching IBM cards for plant accounting (maintaining appropriate control of government-owned equipment) and producing 20,000 cards a month for "employees working on Laboratory problems."[2] Additionally, "A master deck of cards containing personnel information is used to prepare regular personnel reports…" and punched

---

[1] A challenge noted earlier, perhaps disconcerting to those with limited knowledge of Navy laboratories, is their names change more frequently than seems reasonable. As a result, a history like this is forced, particularly covering the period of a name change as does this chapter, to bounce from one name to the other. The previous chapter reported NEL became NCCCLC in 1967, then NELC; NOTS became NWC; and pieces of both became NUWC. And yet this later chapter continues to discuss NEL and NOTS. We will do our best to cite the correct organization name *at the time an event occurred*. The reader's patience is appreciated.

[2] NEL *Calendar*, Sept. 1, 1961, 1.

cards would maintain records of classified information for required inventories.

Within five years, NEL would create a Data Processing Division, formalizing its expanding work related to digital information technologies. Off-the-shelf UNIVAC computers would be programmed and integrated into systems for shipboard communications as well as data analysis on sea and land. In July 1966, USS *Marysville* (EPCER-857) left San Diego for the equatorial Pacific to study ocean temperatures and currents. As part of its advanced research gear, *Marysville* carried a UNIVAC 1218 to process data collected during the cruise.[3]

Although it had worked in technical project computing for some time, NEL now entered the digital computer age with enthusiasm. In May 1961, the first NEL Commanding Officer and Director's Special Honorary Award for Scientific Achievement had been presented to the head of the Theory Analysis and Computer Branch. (The 2 June 1961 *Calendar* reported the award was to be presented annually at each Bureau of Ships laboratory; laboratory recipients subsequently would be considered for a bureau award.) Dr. Maurice Halstead was honored for conceiving and developing the NEL International Algorithmic Compiler (NELIAC).[4] A product of early NEL research into the theory and utilization of computers, NELIAC compiled programs in problem-oriented language and boasted a language translation method for greatly accelerating computer data input. Billed as the world's first self-compiling compiler, it was significant in development of the Naval Tactical Data System. Halstead taught classes at the University of Southern California and the UC Extension on the subject, and wrote a book.[5] He reported "several industrial units, a religious organization, a European military headquarters and a number of universities are actively pursuing the subject—this is in addition to four Navy installations and three Army installations now using the system."[6]

Barbara Houlton, a 1959 math and physics graduate of Duke University,

---

[3] *Marysville* made frequent cruises in support of oceanographic research from 1946 until her retirement in 1970.

[4] Dr. Harry D. Huskey, mathematics professor at UC Berkeley, is noted as developer in some references; since he wrote the preface to Halstead's book, and they appeared at a symposium for which *Calendar* (February 15, 1963) called them "founders of NELIAC," it is reasonable to assign them somewhat equal rights.

[5] *Machine Independent Computer Programming* (Washington, D.C.: Spartan Books, 1962).

[6] NEL *Calendar*, 15 February 1963, 4.

arrived to work as a contractor in Halstead's group in 1962. NELIAC, she said,

> was called a self-compiling compiler…this was a single focus effort, computers on computers. So I liked that, systems programming, and they already had a NELIAC compiler going, which worked for a computer that they had at the lab… transitioning the NELIAC that we had to the Burroughs D825, which was one of the first multi-processors at that time. It was just single-thread processing for computers in general… we used NELIAC to develop an assembler. We got one of the first rotating disks, which would be mass storage, and we extended the ability of NELIAC to communicate with other devices…an expansion of the existing work that we had done.[7]

Probably of more interest was the fact the programming language was employed in the lab's assumption of responsibility for computing its own payroll. Managed for decades by the Naval Supply Center, paychecks NEL employees received on June 14, 1963 were printed by the supply center but calculated by their own Accounting Division.[8] (The pay of employees at the tenant Naval Personnel Research Activity and Navy Medical Neuropsychiatric Research Unit was also calculated by NEL.) According to the newspaper, "NELIAC, the NEL developed computer language, is used to instruct the computer for the payroll program."

Dr. Ralph Christensen

Presenting that award to Maurice Halstead in 1961 were Captain Frank B. Herold, commanding officer and director since September 1960, and Dr. Ralph Christensen, covered in *Calendar* upon his selection as technical director.[9]

As noted in Chapter 1, Christensen was one of the first scientists invited by Dr. Vern Knudsen to join the University of California Division of War Research. When UCDWR terminated in 1946, it might have been more reasonable for Christensen (often referred to as a "scientist's scientist") to join the pure-research-focused effort at the Marine Physical Lab; instead he transferred with a large number of former UC employees to the Navy Electronics Laboratory. He served as head of the Sonar Branch and later the Signal Propagation Division, overseeing major studies of underwater acoustics, including the LOng-Range Active Detection (LORAD) program and its successor, the Forward Area SOnar Ranging (FASOR) project. These studies generated a tremendous amount of data that

[7] Barbara Houlton, oral history interview conducted June19, 2018 by Tom LaPuzza, 3.
[8] NEL *Calendar*, 14 June 1963, 1.
[9] NEL *Calendar*, 10 March 1961, 1.

required analysis. Christensen directed a substantial expansion of computing facilities and personnel to provide needed analysis resources.

In 1958, he became associate technical director for research, and, when Technical Director Dr. F.N.D. Kurie became seriously ill, he took over as acting TD. In 1961, the Bureau of Ships, after a nationwide search, chose Christensen as technical director.

At the time, NEL was playing a critical role in direct fleet support with projects in surface-ship command and control (e.g., Naval Tactical Data System), the beginnings of satellite communications, and on-board presence for establishing Arctic submarine capabilities. On the other hand, large numbers of laboratory personnel were involved in basic research. Christensen encouraged publication of research findings and pushed to maintain intellectual standards commensurate with leading universities. He urged filing of patents and fostered a personnel interchange with the Naval Postgraduate School. Although his administrative duties substantially increased as he rose higher in the organizational structure, he took an active interest in the scientific work being done under his direction. Those researchers who worked for him recalled the demanding questions he put to them, challenging their findings, and suggesting or requiring revision or amplification.

Christensen's philosophy as technical director was NEL concentration on a limited number of projects with the laboratory performing most of the work in-house with its own technologists. He questioned the movement toward systems engineering and contract monitoring, preferring to concentrate on basic research.

Within a year of his selection as TD, Christensen announced a reorganization of NEL, which at the time had only one "Scientific Department." He appointed as the key managers in that department associate technical directors for underseas technology (Dr. Donald A. Wilson), electromagnetics technology (Edwin B. Robinson), and data systems and evaluation (Charles S. Manning), directing them to assume most of the technical responsibilities managed by the department's former division offices. He also assigned them some functions previously handled by the TD's office. In the new structure, the underseas technology associate TD managed a dozen divisions or division-like organizations, while the other two had that number between them. Scientific personnel were assigned to a specific division head, but reassigned to operating managers when they were tasked for a project. When the project ended, they would revert to the supervision of the division head.

Christensen explained his philosophy for that procedure:

> Research and certain types of exploratory development are best served by a fair degree of continuity of personal assignment. Without this, the building of high experience and competence levels in individual scientists and engineers would not be possible. The functioning of the new organization is designed to protect this kind of assignment continuity…[10]

Over the next half-dozen years, NEL personnel pursued a variety of projects in all three areas managed by the associate TDs. For example, Chapter 8 described the dives of the bathyscaph *Trieste*, one to the bottom of the sea. As detailed in Chapter 6, NEL integrated contractor deliverables into the highly successful Naval Tactical Data System. Voyages to the top of the world continued, providing Navy submarines with under-ice navigation capability essentially developed by Point Loma civilians. And there were communication projects underway as well.

Shipboard communication

In July 1963, the chief of the Bureau of Ships (BuShips), Rear Admiral W.A. Brockett, announced his organization and the Navy Electronics Laboratory had "embarked on a comprehensive program of integration for shipboard communications facilities."[11] Citing many years of individual, unconnected projects providing a variety of communication capabilities that separately and *in toto* were "not satisfactory," he announced a concentrated effort, with NEL as lead, to integrate Navy command and communications. The desired results were "improved performance, reduced procurement and maintenance costs, and increased operational effectiveness." The effort had begun three years earlier, when the Chief of Naval Operations directed convening a Naval Communications Advisory Board "to analyze immediate and future Navy communications requirements."[12] Their findings stimulated a new Naval Advanced Communications Plan (NACP) with half a dozen major conclusions:

> a. The demand for rapid and reliable exchange of <u>a greater volume of data</u> between <u>larger numbers of combat units</u> over a <u>more diverse variety of communication</u> media is <u>critical</u> and will <u>continue to increase</u>." (Emphasis in original)

---

[10] NEL *Calendar*, 25 May 1962, 2.
[11] U.S. Navy Electronics Laboratory, *Southern Cross, Vol. 1*, "Naval Ships Advanced Communications," July 1963.
[12] "Naval Ships Advanced Communications," 7.

b. Unsatisfactory conditions in shipboard communications are primarily due to an over-the-years accumulation of equipments designed to perform specific tasks as isolated units… [13]

c. Design of a unified electronic system directly into the hull as an integral part of the total ship complex is recommended for future warships. System integration will decrease initial costs; reduce power, space, and support requirements; and minimize intra-system and hull-electronic interference.

d. Immediate fleet-wide adoption of fully integrated ships is not technically or economically feasible. Conversion should be evolutionary…

e. The most pressing need is for shipborne command and communication centers…

f. The long-range intent of NACP is the evolution of a global network capable of assuming the full load of essential communications after nearly complete devastation of land facilities. Its immediate aim is the development of a progressive series of shipborne communications systems functioning as an integral part of a joint command, control, and coordination complex.

The publication reported previous major contributions of Navy technologists to communications science and engineering, but acknowledged the service's expanding missions (citing specifically "extension of air and undersea warfare into the Arctic regions," substantially based on NEL efforts) had resulted in the increasing requirements cited in the plan's first conclusion.[14] Cited as a major challenge resulting from expansion of shipboard communication equipment was "component interaction and self-interference," a challenge NEL had been working since shortly after World War II.

To address concerns/conclusions in the communications plan, BuShips initiated the Southern Cross Technical Development Plan (the formal new technology acquisition process discussed in the previous chapter), consisting even in the early years of more than thirty sub-programs for technology development and "a multitude of research and research-monitoring projects."[15] Under Southern Cross, NEL was tasked to develop and test the Naval Ships Advanced Communications System, with dual objectives of near-immediate development of integrated command-communications capabilities for existing ships and the longer-term requirement to evolve fully integrated ships for the future.

---

[13] Comment of reviewer Carmela Keeney, retired SSC Pacific Executive Director: "'Stovepiped systems' continue to exist into 21st Century!"

[14] A dramatic example from Page 4 of the document: "In 1912, USS NEW JERSEY [sic] put to sea with one receiver-transmitter; in 1946, a later NEW JERSEY carried 150 electronic assemblies; and in 1962 the electronic plant of USS TICONDEROGA [sic] consisted of 262 equipments, each comparable in size, weight, power, and support requirements to the lone unit in the 1912 warship."

[15] "Naval Ships Advanced Communications," 12-13.

The initial "targets" were numbered-fleet flagships (e.g., Second Fleet, Sixth Fleet). There were two reasons for this: communication improvements had been made over time to ship echelons above and below numbered fleets, but not to those; and, "the command-communications functions of the numbered-feet flagship… must control and coordinate the operations of a force so diverse that it is comparable to a small self-contained navy."[16] The publication cited a recent exercise in which a numbered-fleet flagship, "a guided-missile cruiser with 200 major electronic assemblies on board—was in meaningful contact with shore installations for only one third of the total exercise time."[17] Self-interference was the stated cause for that dismal performance of its electronic connections.

The magnitude of this comprehensive communication improvement effort required a substantially long-term schedule, and there was concern about timing of technology insertion, specifically the tendency to add new technology near project's end. That practice often resulted in expensive compromises and/or degraded system performance. To avoid those, NEL proposed a Ships Advanced Communications Operating Model. A key element of that model was to obtain a decommissioned warship and develop the new integrated communications suite aboard it before introducing it to the numbered-fleet flagships.

The project, with sparse detail, was introduced in an early 1963 issue of Calendar.[18] Headlined "Floating Laboratory Under Consideration," the article explained the concept of drawing a ship from the mothball or reserve fleets and positioning it off Point Loma, half a mile from shore, behind a breakwater, with a causeway constructed to connect it to the beach. The article reported,

> Such a seabome research installation would be the first of its kind… Location of the laboratory on the oceanside [of Point Loma] would permit research studies in conjunction with actual fleet and shore operations distant from San Diego. The floating laboratory would supplement the work of the ship antennae [sic] model range.

The plan became reality in late 1965, when the decommissioned aircraft carrier ex-USS *Bunker Hill* (variously CV/CVA/CVS-17) was towed to San Diego. The *Essex*-class ship had joined the fleet in mid-World War II, but after two years of distinguished service had been badly damaged by suicide planes during the invasion of Okinawa. After repair, she returned to service, transporting veterans home from the Pacific Theater, then was deactivated in the reserve fleet

---

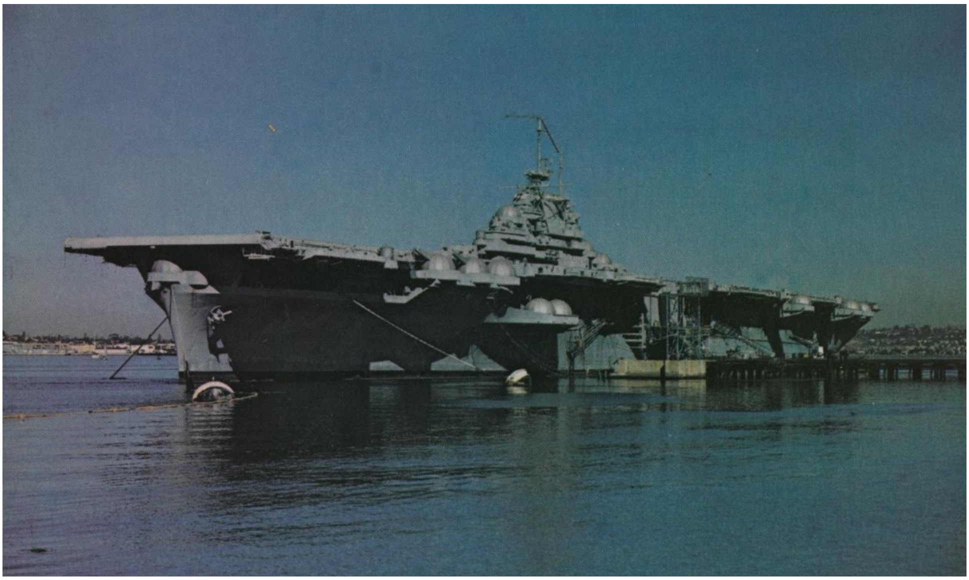
[16] "Naval Ships Advanced Communications," 11.
[17] "Naval Ships Advanced Communications," 6.
[18] NEL *Calendar*, 18 January 1963, 1.

at Bremerton until NEL's quest for an electronic test laboratory focused on her. The ship, now designated AVT-9 (Aircraft Transport, Auxiliary), arrived December 7, 1965, docking at Naval Air Station North Island, directly across the bay from NEL's Waterfront Area. It would remain there for half a dozen years.

A *Calendar* a few days later reported the ship was to be used for the Southern Cross program, based upon "designing and organizing a ship's communications resources as an integrated system characterized by reliable, high-speed processing and distribution of traffic, and rapid, effective control of the ship's communication facilities."[19]

Significant was the plan to analyze and project shipboard communications requirements for the next decade.

Documentation on change of venue (from the planned open ocean anchorage west of Point Loma to the sheltered bay east of it with line-of-sight to the sea effectively blocked by the point's 400-foot-high bulk) could not be found, but the



The World War II-aircraft carrier ex-USS *Bunker Hill* (now AVT-9) was stationed for half a dozen years off Naval Air Station North Island while NEL personnel conducted a number of communication equipment development and testing operations aboard.

[19] NEL *Calendar*, December 10, 1965, 1.

decision certainly reduced the cost, engineering requirements, and time delay necessary to fabricate the causeway and breakwater.

A ship requires a captain, so Lieutenant Ben W. Wright, an NEL assistant communications program officer, was assigned as officer-in-charge. Replacing the active carrier's 90-100 aircraft and 2,600 crew members were thirty-six NEL scientists, engineers, and technicians; thirteen enlisted personnel who maintained equipment; and a security and maintenance force of a dozen.

Communications goals outlined

Several months prior to the carrier's arrival, a seemingly unconnected meeting was held at NEL, titled the ICS (Integrated Combat System) Project Review and Planning Conference. As will be discussed later in the chapter, it was an effort of the Navy's Anti-Submarine Warfare Systems Program Office to organize and coordinate numerous (and disparate) Navy ASW efforts and projects.[20] Having no specific connection to that effort, Peter Duncan of the Operations and Systems Analysis Division nevertheless presented one of NEL's five papers. (*Calendar* printed names and subjects of lab speakers, but neither his name nor topic was listed, so perhaps he was a last-minute addition.[21]) He spoke on "Southern Cross," advising about the lab program for which the *Bunker Hill* would soon arrive. Duncan reported the program advanced development objective had been signed by the Chief of Naval Operations, specifying an understandably desirable but almost impossibly optimistic goal: "Southern Cross is the Navy's most far reaching communications R and D project," emphasizing *R and D project*:

> It will elevate the status of naval communications from today's complex, cumbersome, troublesome, slow, and inefficient accumulation of equipment of widely different types and vintages to a modern, automatically controlled, high-speed, error-free, secure, easily maintained, integrated system that is designed, tested, and installed as a unified communications package… This is the only program now going which addresses itself to this problem in this manner—overall improvement in shipboard communications, Navy-wide.[22]

Although the project planned aboard *Bunker Hill* focused on the widely

[20] "Proceedings of the ICS Project Review and Planning Conference," 14-16 September 1965, NEL Report 1330, 16 November 1965.
[21] NEL *Calendar*, September 10, 1965, 3.
[22] Proceedings of the ICS Project Review…" 342.

varying communications requirements of a numbered-fleet flagship (specifically because of that wide variance), the results were intended to benefit almost every surface ship in the Navy—destroyers, cruisers, carriers, and some amphibious ships, since the long-term goal was development of a family of Naval Ships Advanced Communication Systems (NSACS). The numbered-fleet flagship was merely the starting point. Duncan emphasized the novelty of the effort: "Instead of piling box on box, as we have done for years, the idea is to start from the ground and build an integrated communications system."

His team had gone to unusual lengths to engage fleet sailors, contacting communications personnel on fifty destroyers from First, Second, and Sixth fleets, plus WESTPAC (Western Pacific area of operations) returnees, to fill out a simple form so the engineers could determine reasonable requirements. Demonstrating (and obviously contrasting) the real present and anticipated future of shipboard comms, he told ICS conference attendees,

> We find, for example, that Commander Seventh Fleet has 117 enlisted men and 20 officers involved in communications functions. Our system, by comparison, would employ 58 enlisted men and 9 officers… File keeping presently requires communications center files, crypto center files, radio station files, visual files, general message files, broadcast files, fax file, tickler files, and relay file. All these things we hope to consolidate into one file, a tape or disc file with capability for fast retrieval.[23]

Duncan emphasized Southern Cross was not a project to develop this panacea of shipboard communications, but was designed to determine how many and which of the desirable attributes of such a system could be achieved, and at what cost. Eventually that effort would evolve into an actual development.

In the meantime, the NEL pre-design project report was nearly complete. It outlined four phases: "technique studies and preliminary system planning (FY 1963-1964)"; a consolidation period to identify general features of NSACS platforms and specific implementation for the fleet flagships; fabrication of a developmental system; and, finally, system evaluation. (The report was considered conclusion of the project's second phase.[24]) *Bunker Hill* was crucial to the latter two phases, as the developmental system would be installed aboard, and the integration, test, and evaluation of the fourth phase would resolve technical

---

[23] "Proceedings of the ICS Project Review…" 345.

[24] "Naval Ships Advanced Communication System for Numbered Fleet Flagship (NSACS/NFF)," NEL Report 1309, January 1966, v.

tradeoffs and demonstrate system effectiveness. Operational Evaluation of the system aboard a numbered-fleet flagship was programmed for Fiscal Year 1971.

One significant aspect of the project was limiting resources dedicated to fixed circuits or users, essentially sharing equipment among all communicators. Equipment on working frequencies would be dedicated to a user only for the communication exchange, then available to other users. The report predicted, "Initial calculations indicate that some 30 to 40 percent reduction in the number of transmitters required can be effected by operating in this manner rather than using the current practice of dedicated circuits and nets…"[25]

The NSACS for the numbered-fleet flagship was only one of a number of total-ship comms systems planned, although it was considered the most complex.

Platform accessibility

One of the major challenges for military research and development engineers was (and is) gaining credible access to platforms they intend to improve or arm with new weapons. As noted in Chapter 3, Navy Radio and Sound Laboratory engineers used a small boat to circle ships in San Diego harbor to characterize antenna performance during World War II. The construction of the Shipboard Antenna Model Range after the war allowed development of *new technology* antennas prior to ship construction, but the problem remained that assessment and improvement of *existing* antennas generally required going aboard the ship and potentially disrupting operations while conducting antenna experiments.

The Naval Ordnance Test Station addressed its similar problem—the need for aircraft and pilots to test air-launched weapons—more effectively through assignment of a naval air unit and upgrading of and addition to its airfield facilities. Initially, Caltech's Dr. Charles Lauritsen had convinced the Commander, Fleet Air, West Coast that Navy pilots and aircraft desperately needed new weapons and he desperately needed pilots and aircraft to support the development of those weapons. With that for justification, a small experimental air unit was ordered to support the Caltech rocket program. Starting with one plane, one pilot, and one mechanic in spring 1943, in six months there were sixteen officers and more than

[25] NEL Report 1309, viii.

a hundred sailors, and ultimately an active-duty unit, Air Development Squadron VX-5 (later VX-9) was assigned permanently to the air weapons facility.[26]

One squadron pilot recalled being invited to a presentation on a proposed new piece of ordnance. He acknowledged understanding only about ten percent of the technology discussion, but recognized he was there to "see if there was anything really stupid in it…"[27] It was, in essence, a reiteration of the civilian technologist (Dr. Charles Lauritsen) and the military pilot (Captain Sherman Everett Burroughs) recognizing they needed one another, critically, to get the job done.

Given the Navy could not dedicate a surface ship squadron to test new comms antennas and command centers, the arrival of *Bunker Hill* in San Diego was a godsend. Almost immediately upon the carrier's arrival, a team from NEL began refurbishing shipboard spaces for the first assigned tasking: development and testing of the Naval Ships Advanced Communications System (NSACS).

Coincidentally and almost simultaneously, a similar refurbishment on another World War II relic was underway, across the bay on top of Point Loma. Battery Ashburn, constructed between June 1942 and March 1944 against the worrisome possibility of an invasion, was equipped with two sixteen-inch 50-caliber guns capable of launching a shell weighing more than a ton twenty-five miles to sea. Each gun was test-fired only once, in July 1944.[28] The battery had been declared surplus in May 1948, its guns sold for scrap, the fortification abandoned.

NEL, desperate for space to support sponsor tasking, saw promise in the battery for two significant efforts, and decided to renovate Ashburn. The first project began in the mid-1960s, when the Bureau of Ships tapped NEL as its lead laboratory for microelectronics. Long-range plans were developed, completed in December 1965, and initiated shortly thereafter. They included "work in systems applications; applications techniques; research; and support (primarily to BUSHIPS [sic] in its contracting for microelectronics)."[29]

---

[26] Elizabeth Babcock, *History of the Naval Weapons Center, China Lake, California, Volume 3: Magnificent Mavericks* (China Lake, California: United States Naval Museum of Armament and Technology, 2007), 420-424.
[27] Cliff Lawson, *History of China Lake, Volume 4: The Station Comes of Age* (China Lake, California: United States Navy Naval Air Warfare Center Weapons Division, 2017), 156.
[28] H.R. Everett, "Modernization batteries," *WWII Harbor Defenses of San Diego* (McLean, Va.: Coast Defense Study Group Press, 2021), citing H.B. Overton, The 19th Coast Artillery and Fort Rosecrans: Remembrances (National Park Service, January 1993).
[29] NEL Command History, 1965-1967, 7.

Integrated Circuit Fabrication Facility

The development of electronic technology was clearly one of the most important stories of the twentieth century. It might have been otherwise but for several critical examples of human wizardry: development of the transistor, and microelectronics/Large-Scale Integration (LSI). The first, the invention of the point-contact transistor, was the Nobel Prize-winning work of three scientists working for Bell Laboratories—John Bardeen, Walter Brattain, and William Shockley (whose son Dr. Richard Shockley, incidentally, worked at the Point Loma Navy laboratory for four decades). The transistor replaced the vacuum tube in devices powered by electronics; had that not occurred, the necessarily huge (building-size) information processing systems might well have doomed, or at least stifled, the electronics revolution. Certainly, a device requiring thousands of fragile glass vacuum tubes would have received a chilly welcome on a Navy ship.

Microelectronics took the process an infinitesimally large step further, as it allowed placement of thousands of transistors (and resistors and diodes) on a tiny chip of silicon. And LSI, which was coming, took it even further, allowing placement of thousands of integrated circuits on a single chip.

Battery Ashburn, with its feet-thick concrete walls to protect the guns from incoming ordnance should that feared invasion have occurred, provided the ideal constant-temperature, vibration-free environment to fabricate tiny electronic circuits. Labs were constructed for fabrication and testing; materials and chemistry labs were added for research; ultra-high vacuum systems were installed for a "clean" room to filter out the smaller impurities in the process.

A report published in the summer of 1966 outlined "a sound basis… for the continuing development of microelectronics."[30] Among other things, it suggested, "Fabrication of films of highest purity by means of modern ultrahigh-vacuum techniques," and "Measurement of optical and other properties of the films" under various temperatures and pressures at the integrated circuit facility.

Here, for the next several decades, pioneering achievements would be made in reducing feature size of integrated circuits (ICs) and providing radiation hardening to those circuits. Designated as the Navy's primary RDT&E facility for

[30] T.G. Pavlopoulos, "Optical Properties of Metals and Semiconducting Materials," NEL Report 1397, 27 August 1966.

design and fabrication of silicon integrated circuits, its assigned responsibilities were to develop advanced silicon-based IC and sensor technology, maintain in-house Navy expertise in their fabrication, and provide fabrication services to users of novel or unavailable ICs and related technologies.

Message Processing and Distribution System

The second NEL project at the defense battery involved a shipboard system to improve message handling, the first operational system emerging from the NSACS project. While Battery Ashburn North was being renovated to house the integrated circuits lab, Ashburn South was receiving an almost simultaneous upgrade to support development of that system, initiated on the *Bunker Hill*.

In mid-1966, reacting to the intensifying combat situation in Vietnam and the Navy's need for better communications in theater, Naval Ship Systems Command (successor to the Bureau of Ships) tasked NEL with designing a computerized system for expediting message handling, storage, and recording aboard the guided missile cruiser USS *Oklahoma City* (CLG-5). The cruiser, which relied on telephones and handwritten messages for internal communications, had served previously as the Seventh Fleet flagship, and was slated to return to that duty. Prior to that reassignment, an upgrade of internal communications was considered essential. A team headed by Howard Wong, which had completed extensive groundwork under the NSACS advanced communications effort on *Bunker Hill,* was able to react rapidly to set up an assembly and test facility in Battery Ashburn South. Using existing major components, such as the Naval Tactical Data System computer and peripheral equipment, Wong's team, which included co-located contractors responsible for message entry and distribution devices, assembled and integrated system components. Simultaneously, officer and enlisted personnel from the ship's crew were on-site, being trained by lab personnel to use and maintain the equipment.

In mid-May 1967, less than a year after concentrated MPDS development began and a month ahead of schedule, the equipment was trucked to San Francisco for installation on the cruiser. On board and operating, its capability to record, distribute to correct end users, store, and locate up to 5,200 messages substantially improved internal shipboard communications:

> The net effect of the MPDS is to mechanize or eliminate most of the manual repetitive tasks which now delay information transfer and waste manpower. This permits better use of communicators for those operations requiring human discrimination and decision-making.[31]

As *Oklahoma City* was deploying with its state-of-the-art internal communications equipment, the U.S. Congress was authorizing a massive expenditure of funds for a class of "supercarriers," the lead ship of which was USS *Nimitz* (CVAN/CVN-68). During the four years the carrier was under construction, NELC (The "N" was changed to "Naval" and the "C" for "Center" added in July 1967) personnel had begun assembly of a fully automated MPDS aboard *Bunker Hill*. As envisioned in the initial acquisition plan for the carrier, the lab staff could monitor the effects of shipboard humidity, power fluctuation, and metallic influence on the sensitive components, all without disrupting an operational vessel. As the first supercarrier took shape in Newport News, Virginia, laboratory personnel were completing the advanced version of MPDS that, outfitted with distributed printers, would become original equipment on *Nimitz*.[32]

In June 1969, the Navy awarded a contract for commercial development of "cathode-ray tube displays, alphanumerical and function keyboards, and related electronic units" to form the essential elements of the MPDS suite aboard *Nimitz*.[33] A *Calendar* article published at that time noted MPDS "increases more than fivefold the speed of message delivery and the volume of traffic that can be handled aboard ship while at the same time permitting a decrease in manpower."

It would require another five years, but the NELC newspaper would report in mid-1974 that MPDS had "processed its first real-world message traffic" using the system.[34] Like the USS *Oklahoma City* crew previously, the communications team of *Nimitz* had been trained in *Bunker Hill*, which was also the site of the Technical Evaluation (TECHEVAL). The completed system had been delivered to the shipbuilder for installation on the carrier in mid-1972. Work then began almost immediately on an identical equipment suite for USS *Eisenhower* (CVAN-69). With the decision to employ *Bunker Hill* as a platform for underwater shock tests,

---

[31] NEL *Calendar*, May 13, 1967, 2.
[32] Kenneth L. Whitten, "The Message Processing and Distribution System Development" (Thesis) (Monterey, California: Naval Postgraduate School, June 1981), 8–9. Also, Naval Ocean Systems Center, *Fifty Years of Research and Development*, 79.
[33] NELC *Calendar*, July 3, 1969, 1.
[34] NELC *Calendar*, May 24, 1974, 3.

Employing the ex-USS *Bunker Hill* (AVT-9) as the development and testing site, NEL engineers put together Message Processing and Distribution Systems for USS *Oklahoma City* (CLG-5) (left) and USS *Nimitz* (CVN-68), tested them, and trained ships' crews in their use.

NELC moved the *Eisenhower* MPDS work ashore to one of its laboratories.[35] The Center also continued its responsibility for software configuration management on the system until that task was assumed by the Fleet Combat Direction Systems Support Activity.

Several years after she arrived, *Calendar* had run a lengthy story chronicling the various laboratory projects taking advantage of *Bunker Hill*.[36] In November 1972, the ship was towed to sea and used as a target for underwater shock tests.

Howard Wong

After military service in the Air Force, Howard Wong attended San Diego State College, earning a degree in electrical engineering. His civilian career began in 1959 at NEL as an engineer-in-training on the Naval Tactical Data System. After involvement with several aspects of NTDS, he participated in the

[35] NELC *Calendar*, November 10, 1972 and May 24, 1974.
[36] NELC *Calendar* March 1, 1968, 1.

development effort that initiated what became one of the Center's premier facilities, the Integrated Circuit Fabrication Facility. In 1966, he was selected to lead the highly successful team developing MPDS described immediately above.

In May 1970, he began a lengthy run as a division head in the Information Systems/ Information Systems Technology Department. With the establishment of the Naval Ocean Systems Center in 1977, he served as a division head in the Communications Systems and Technology Department. In the 1980s, he managed development of tactical data link technology. Major systems assigned to his division included the Joint Tactical Information Distribution System, the Command and Control Processor, and the Multifunctional Information Distribution System. A substantial Center resource, the Systems Integration Facility, was established during his tenure.

Howard Wong retired in 1995 after four decades of service to the Center.

ASW conference revisited

Earlier in the chapter, we discussed a meeting held at the Point Loma laboratory, in which an NEL engineer delivered a paper about improving ship communications. As noted, the conference was not about communications. Titled the ICS (Integrated Combat System) Project Review and Planning Conference, it was, in fact, about ASW, specifically about organizing it.

A representative of the ASW Program Office, the meeting sponsor, initiated the meeting by explaining its purpose and the role of the program office:

> The basic purpose of our meeting is to insure continuing and increasing coordination among Anti-Submarine Warfare ship programs and with related projects… to provide centralized management, technical direction, and control of development, production and support of ASW systems and components. This applies to all aircraft, submarines, surface ship and fixed systems.[37]

He emphasized addressing every related project "from the total-ship standpoint."

Some key events led to this conference: the development of the Naval Tactical Data System (NTDS) was discussed in several earlier chapters. Even before the

[37] "Proceedings of the ICS Project Review…" 4.

major news stories covering NTDS success, some important actions occurred: "By 1959, a significant number of NEL personnel were diverted from the NTDS AAW [Anti-Air Warfare] program effort to explore the feasibility of applying a data processing technique to the tactical ASW problem."[38]

(Incidentally, the successful conclusion of their first study led to establishment of the Small Ship Combat Data System program at NEL, which in the mid-1960s provided an NTDS-like capability to smaller ships.[39])

As the former NTDS personnel from NEL were moving from data system development for anti-air to anti-submarine applications, the Navy embarked on an ambitious program to develop several classes of destroyer escort-type ships to replace aging FRAM ships.[40]

Sea Hawk

Among those new ships was one specifically designated by the Chief of Naval Operations to emphasize enhanced ASW capabilities, including speed and endurance, reliability and maintainability, and "integrated ship design, particularly the ship's electronic systems."[41] Powered by quiet-running gas turbine propulsion, design objectives for the ship included a state-of-the-art sonar suite. The program initiated to meet the performance standards was called "Sea Hawk—AGDE":

> In September 1962, Project SEA HAWK [sic] was established, the objective being the design of an optimized ship system capable of effective operation against the submarine threat predicted for the 1970 era. NEL personnel spent over two years determining the requirements for the Command and Control portion of SEA HAWK. NEL was one of seven Navy laboratories assigned the task of delineating the functional details, which were finished by August 1963.[42]

---

[38] "ASWSC&CS: Antisubmarine Warfare Ship Command and Control System Project: Historical Narrative," NEL Technical Document No. 6, March 1967, 2-3.
[39] *Fifty Years*, 76. See also: NEL Command History, 1961.
[40] The Fleet Rehabilitation And Modernization program was a stop-gap measure recommended by Admiral Arleigh Burke to counter the post-World War II surge in Soviet submarine numbers and capabilities. It involved major upgrades of a large number of WWII destroyers to fill the void while new ship classes were authorized and built. Upgrades included NEL sonar technology and NOTS Anti-Submarine Rockets.
[41] U.S. Navy Electronics Laboratory, "Characteristics of the ASW System for the SEAHAWK—AGDE," March 1963, 1.
[42] "ASWSC & CS Historical Narrative," 3.

NEL's contribution to the program was in a sense even more fundamental: on August 2, 1963, NEL Executive Officer Captain Edward C. Svendsen was transferred to the Bureau of Ships to become the Sea Hawk Project Officer.[43] This was, incidentally, the same E.C. Svendsen who had served as Irvin McNally's collaborator in developing the radical concepts of NTDS detailed in Chapter 6, and who carried on that leadership when McNally retired in mid-development.

NEL set up a dedicated Sea Hawk project office in the summer of 1963, with assigned Navy lieutenant commanders as project officer and programming officer. There was also a civilian project engineer. A brief newspaper announcement advised employees of the office, reporting simply, "Sea Hawk is a research and development program for an advanced ASW system."[44]

The two essential program elements were testing of equipment and systems installed on ships and managing parallel shore development. The Point Loma lab and the desert weapons station were key program participants. The Naval Ordnance Test Station was responsible for the fire-control and weapon systems and their integration into the ship,[45] and NOTS Pasadena worked on sonars for which NOTS China Lake engineers wrote operating the manuals. NEL designed and fabricated communications resources and maintained the shore facility.

Another essential element of the Sea Hawk program was the design and construction of a test platform to allow realistic fielding, operation, and evaluation of hardware and protocols for the intended new ship class.

Although some of the literature suggests the lead ship would be named *Sea Hawk*, *Jane's* chronicles in its mid- and late-1960 editions an escort research ship/experimental sonar ship, USS *Glover* (AGDE-1—Auxiliary General Destroyer Escort), launched in spring 1965. With an experimental design maximizing hydrodynamics, the purpose was to determine equipment placement for optimizing sonar performance. She was outfitted with a unique propulsion system, featuring "counter-rotating propellers emerging from an electric motor nacelle at the stern to reduce cavitation," virtually eliminating self-noise.[46] More significant to this discussion, she had "a massive bow sonar dome integral with her

[43] NEL *Station Journal*, August 2, 1963.
[44] NEL *Calendar*, August 9, 1963, 1.
[45] *The Station Comes of Age*, 454.
[46] *Jane's Fighting Ships, 1964-1965* (London: Sampson Low, Marston & Co., Ltd., 1964), 358.

hull and extending well forward underwater."[47] In her stern was a long-range sonar of molded plastic, and a variable depth sonar was mounted in the keel. Fully outfitted as a surface combatant, there were also accommodations for about thirty civilian scientists to perform appropriate performance research.

A March 1963 NEL report focused attention on the planned ASW system for the platform, which was to be its defining mission.[48] The importance of timely delivery of components of the ASW system was emphasized.

Primary objectives outlined in the NEL report:[49] A) Sonar: "The sonar suit will provide both above-layer and below-layer coverage plus first convergence zone and bottom bounce capability." B) Tactical Coordination: "ASW decision-making (tactical) displays will present, in real time and in clear symbolic form, an integrated presentation of the total ASW information available… (NTDS) displays… will be used." C) Computers: "Present standard USQ-20 computers satisfy technical requirements of SEA HAWK… At least two… will probably be needed." Other planned equipment were an SPS-48 radar and a weapons suite including Anti-Submarine Rockets and Mark 46 and EX-10 torpedoes. Among listed performance goals was the "reduction of personnel requirements to about 75 per cent of those of the DEG-1 [USS *Brooke*] class."[50]

One of the critical elements of the Sea Hawk concept, as noted above, was the Shore Test Facility, sited at NEL. In the introduction to the ICS conference, the ASW Program Office representative had advised attendees the shore facility would "expand… in an evolutionary way until it becomes the ICS." He noted that expansion must match the development of the conformal array sonar slated for installation on USS *Glover*. Also, "The AGDE test program …will support the ICS design by measuring the effectiveness of techniques for applying multi-sensor data to fire control solutions which may involve multiple targets."

Although USS *Glover* put to sea as the Sea Hawk test platform and continued in the role of testing new ASW technologies, "for a number of reasons not relevant

---

[47] *Jane's Fighting Ships, 1969 1970* (London: Sampson Low, Marston & Co., Ltd., 1969), 432.
[48] "Characteristics of the ASW System for the SEAHAWK-AGDE (U)," NEL, March 1963, 2.
[49] "Characteristics," 8-9.
[50] *Brooke* was lead ship of one of the several classes of destroyer-escort types the Navy put to sea in the early to mid-1960s. They were "the first small ships of the destroyer escort type ever designed to carry guided missiles," according to *Jane's Fighting Ships, 1967-68*.

here, SEA HAWK [sic] was reduced in scope from a totally integrated ship program into several subtasks, one of which was the ASWSC&CS program."[51]

ASW Ship Command and Control System

The Anti-Submarine Warfare Ship Command and Control System (ASWSC&CS) project—closely related to NTDS, the Small Ship Combat Data System, and the Sea Hawk project—was established to improve command and control for the Navy's ASW forces. It was a

> computerized digital data processing and display system designed to provide improved coordination and control of ASW task groups, and to enhance the performance of a single ship. In collecting, processing, evaluating, and communicating ASW information, ASWSC&CS utilizes the tactical units and ASW weapons available to the commander more effectively than the conventional means.[52]

The three major sub-systems of ASWSC&CS were data processing, display, and communications (obviously consistent with the major sub-elements of NTDS for the anti-air warfare environment).

A proposed plan for developing an ASW Integrated Combat System was issued in August 1964, with CNO staffers issuing guidance "for a Command and Control system to form a nucleus for ICS." The office of the Secretary of the Navy concurred and in December the Bureau of Ships advertised a contract for "design, analysis, operational and test computer programs, system description, documentation, fabrication of keyset entry hardware and other special purpose items to support ASWSC&CS for *two 1047-class DE's*, a CVS, and a test facility at NEL."[53] (Emphasis added)

---

[51] "ASWSC&CS Historical Narrative," 3.
[52] "ASWSC&CS," 1.
[53] "ASWSC&CS," 2. There was no 1047 class of destroyer escorts. DE-1047 itself was USS *Voge*. The appropriate class was USS *Garcia* (DE-1040), consisting originally of ten ships, designated frigates in 1975; in 1979 USS *Glover* was included in the class. Based on commissioning dates and some reading in between the lines, the two DEs equipped with ASWSC&CS were USS *Voge* and USS *Koelsch* (DE/FF-1049), a fact confirmed by the 1968 NELC Command History. The same source identified the carrier as USS *Wasp* (CVS-18). The ASWSC&CS document states, "It was evident to all concerned that the CVS system was adequate, but that the DE system was marginal as far as the display system was

In April 1965, meetings were held "to discuss system operational requirements and equipment interfaces as a preliminary to initiation of the system design." In addition to representatives of the Office of the Chief of Naval Operations and the Bureau of Ships, attendees included personnel from NEL and NOTS Pasadena.

As part of the Sea Hawk project, NEL had been allotted sixteen officer billets; a number of them were reassigned to ASWSC&CS. Additionally, according to a paper presented at the ICS conference by a NOTS engineer, "Commencing with FY1966 the Sea Hawk project was reoriented into what is now the ASW Ship Integrated Combat System."[54]

One of the NEL presenters at the ICS conference, writing about a significant subject for Sea Hawk and then for the ASW Ship Integrated Combat System, defined "ship control":

> By a ship control subsystem we mean the total environment of men, machines, sensors, and computers in an integrated combination to provide information (such as ship's status and tactical orders), and a capability for safe and complete control of the ship's rudder and propulsion plants in any physical or tactical environment.[55]

Thus, as the time neared when the Navy would reorganize its West Coast labs, individuals and groups at China Lake, Pasadena, and San Diego were already proceeding with a joint effort to develop a shipboard integrated ASW system.

Technical Evaluation (TECHEVAL) of the ASW Ship Command and Control System was completed successfully in July 1968 in the Atlantic, with the two destroyer escorts and the ASW carrier playing the principal roles. Numerous surface, submarine, and air units participated in the evaluation, with NELC coordinating and conducting both the single ship and multi-ship tests.[56] Plans were for the Operational Evaluation by Commander, Operational Test and Evaluation Force to be conducted during the current deployment of ASWSC&CS.

NELC also supported the Navy's strategic planning for the Anti-Submarine Force Command Control System, intended to "provide a network of ship and

---

concerned and was extremely limited in computer storage capability."

[54] E.W. Helmdahl, "Position of Naval Ordnance Test Station, China Lake, in ICS Program," "Proceedings of the ICS Project Review…" 71.

[55] W.J. Blumberg, "ASW Ship Integrated Combat System, Ship Control," "Proceedings of the ICS Project Review…" 215.

[56] NELC Command History, 1968, "ASWSC&CS TECHEVAL successfully completed in Atlantic," 16 Oct 1968.

shore-based data processing systems to support command control of Fleet ASW forces in the 1975-1980 era."[57]

Satellite communications

As detailed above, NEL was substantially involved in improving the processing and routing of message traffic once it arrived aboard ship. Prior to that arrival, inter-ship communication was an equally critical element in the success (and sometimes survival) of ships at sea. One of the Point Loma laboratory's primary objectives from its very early days, of course, was improvement of ship-to-ship communication. While such communication is possible using radios, signal flags, and even voice, the undeniable fact the earth is round provides substantial challenge to naval forces required to maintain contact over hundreds of square miles of ocean. In 1962, engineers assigned to NEL's Project Mailbuoy developed the first UHF (ultra high frequency, generally defined as frequencies from 300 megahertz to 3 gigahertz) communication system. The following year the technology transitioned into Project Redglare, "in which a UHF communications repeater in a rocket successfully passed teletype, voice, and facsimile data from ship to shore."[58] Too expensive to employ as a functional comms system, it nevertheless "demonstrated the feasibility of long-range communications through a space-based linkup."

The lab also fashioned two giant fixtures in the early 1960s to pursue satellite communications. On the point itself, a parabolic radio telescope was positioned just off Cabrillo Memorial Drive. It consisted of "a precision sixty-foot paraboloidal reflector mounted on a thirty-five-foot reinforced concrete tower with a MK-32 twin five-inch gun mount employed for control of the elevation and azimuth pointing of the reflector."[59]

For the next decade, it was employed for radio wave propagation studies.

Less than a year after the Point Loma installation, ground was broken for a companion sixty-foot-diameter dish antenna.[60] It could receive and transmit (the

---

[57] NELC Command History, 1969, 10; NELC Annual Report for FY1971, 15.

[58] *Fifty Years*, 69.

[59] NEL *Calendar*, 16 August 1963, 1.

[60] NEL *Station Journal*, 15 May 1964.

Point Loma dish could receive only), but unfortunately it “radiated energy levels hazardous to personnel and the necessity to provide an environment for ultrasensitive reception free from noise and interference” was essential.[61] As a result, it was positioned at a remote site in the Laguna Mountains sixty miles east of San Diego, at an elevation of 3,900 feet. The antenna was required for “Microwave Space Relay communications. The system will provide the Navy with the capability of communicating reliably, rapidly, and with high capacity from ship-to-ship, and ship-to-shore, regardless of the conditions of radio propagation.”

Based on safety and environmental concerns, NEL erected its 60-foot radio telescope at La Posta in the Laguna Mountains, 60 miles from the lab. It was instrumental in microwave research and solar studies.

Over its several decades of operation, it was known by various titles, including prototype satellite communications shore station antenna, radio telescope installation, the La Posta lab/facility, and La Posta Astro-Geophysical Observatory. Completed in November 1965, it supported solar radio mapping,

---

[61] “Prototype Antenna Under Development,” NEL *Calendar*, May 22, 1964, 2.

studies of environmental disturbances caused by extraordinary solar events, and microwave research. In addition to its contributions to satellite communications research, the facility monitored atmospheric disturbances caused by solar flares during a number of NASA space flights in the 1970s.62 Concerns focused on potential for radiation physically harmful to astronauts as well as disruption of radio communications between them and space agency officials on the ground.

First SATCOM experiments

The National Aeronautics and Space Administration (NASA) had launched the Echo 1 satellite in August 1960. The one-hundred-foot diameter balloon functioned as a passive reflector of communication signals. NEL conducted its first satellite communications (SATCOM) experiments with Echo 1. Over the next decade, satellites were launched by NASA, the Department of Defense, and private telecommunications companies, which allowed the laboratory and others to advance the state-of-the-art of SATCOM. By mid-decade, NEL radio scientists had provided the Navy with a system for over-the-horizon communications.[63]

Most significant of the early efforts was NELC's (laboratory name change occurred in 1967) use of the Lincoln Experimental Satellite Number Six to relay communications from a transmitter on Point Loma to USS *Providence* (CLG-6), first as it was tied up at a pier and operating in waters around Tahiti, and then as it steamed across the Pacific toward San Diego. (Tahiti was chosen as the test site due to its normally poor radio wave reception.) The successful transmission utilized a UHF satellite relay and an NELC helical antenna as the primary receiving system. Among other achievements, it demonstrated "the simplicity of providing the present HF Fleet broadcast system with a satellite link."[64] A team led by radio pioneer R.U.F. Hopkins (who incidentally had been the one turning over the shovel of earth at the ground-breaking for the La Posta facility) was aboard *Providence* both at the dock and underway in the Pacific.

Robert U. F. Hopkins, familiarly known as "Hoppy," was an early (September 1941) employee of the U.S. Navy Radio and Sound Lab. He met his

---

[62] See NELC *Calendar* Jan. 29, 1971; July 30, 1971; Dec. 8, 1972; NOSC *Outlook.*
[63] *Fifty Years*, 69.
[64] NELC *Calendar*, June 6, 1969, 1.

future wife Sarah when the two joined a carpool between their homes in Long Beach and their work sites on Point Loma. (See Chapter 5 vignette for more on Sarah Hopkins.) After working on the Navy's first radar, CXZ, Hoppy performed early research on tropospheric ducting, studies that gained an international reputation for NEL. He participated in the Admiral Byrd expedition to Antarctica, and developed a communication network in the Philippines. In the 1960s, he was involved in development and operation of the antenna dishes on Point Loma and at La Posta, resulting in early leadership of NEL/NELC in Navy SATCOM.

Also on board, conducting a separate SATCOM experiment, was Jim Rahilly, who demonstrated a commercial "off-the-shelf" receiver, appropriately modified, could provide satellite broadcast reception. He hand-carried the receiver, and "within two hours after boarding ship, perfect satellite communications Fleet broadcast was being received. The captain of the ship was amazed," he said.[65]

The equipment installed by NELC personnel on *Providence* served as a design base for terminals on six ships involved in an Atlantic "Fleet Operational Investigation." While it was on-going, NELC personnel were transmitting and receiving signals from USS *Independence* (CV-62) in Norfolk, Virginia, demonstrating "feasibility of long-distance relay of tactical data via satellite."[66]

NELC engineers conducted early satellite communications experiments with a specially designed antenna on the guided missile cruiser USS *Providence* (CLG-6).

[65] NELC *Calendar*, June 6, 1969, 2.
[66] *Fifty Years*, 69.

A few weeks after the successful efforts in Tahiti, three NELC engineers were aboard USS *Hornet* (CVS-12), the recovery ship for the Apollo 11 astronauts, staffing a Center satellite communication terminal installed on the flight deck to support the recovery. The equipment had been tested earlier aboard the Apollo 9 and 10 recovery ships, and used on the latter for the Vice President to talk to the astronauts in space.[67]

For the next two years, NELC personnel expended substantial efforts improving the capability of ships to receive fleet satellite broadcasts. Electing to reduce rather than add complexity, one group of half-a-dozen engineers and technicians employed a "space-diversity technique" to provide signal reception more reliably and less expensively than the complex antenna arrays that were being developed for shipboard SATCOM. The group's supervisor explained,

> The four simple hemispherical antennas are located aboard ship so that at least one is always exposed to the satellite. If one antenna becomes shielded from the satellite by the ship's structure, another antenna takes over. Individual antenna signals are combined in phase to provide signal enhancement, or array gain.[68]

The four antennas also provided redundancy and contributed to a more uniform antenna pattern in all directions.

Undersea communication

Based on work in underwater acoustics since its very early days, NEL was responsible for maintaining and enhancing the Navy's ability to communicate with its submerged submarines. As cited in Chapter 6, Arctic submarine pioneer Dr. Waldo Lyon emphasized battery-powered boats were essentially surface craft that submerged occasionally, whereas their nuclear cousins were true submarines capable of operating for long periods of time underwater, with little or no surface contact. Given that, a robust underwater communication capability was essential, sinceskippers of SSNs required the capability to provide situational reports and receive operational tasking. As will be detailed in Chapter 13, NEL/NELC technical efforts substantially improved undersea communications capabilities.

[67] NELC *Calendar*, July 19, 1969, 1.
[68] NELC *Calendar*, May 7, 1971, 3.

Navigation technology

During the 1950s, NEL had developed a low frequency radio navigation system called Radux that provided remarkable position accuracy compared to the prevalent celestial navigation capability.[69] Radux was based on a concept proposed by J.A. Pierce of Harvard University:

> The great phase stability of very low frequency transmission permits intercontinental frequency comparison to a precision of at least 1 part in 10^{10}… With such stability of propagation, extremely narrow receiving bandwidths are attainable. These bandwidths, in turn, make possible highly reliable networking of frequencies for communication station allocation and for navigational purposes.[70]

Radux's limitations in terms of node requirements (24) and accuracy ($\pm$3 miles), combined with NEL's study of very low frequency (VLF) signals for submarine communications, prompted development of an interim (1956-1958) Radux-Omega system, which "did establish the suitability of vlf for navigation."[71] The final stage of the effort was Omega. Under this concept, precise measurement of phase differences of VLF signals received from two transmitters (a "master" and a "slave" station) would provide a line-of-position. Measuring phase differences between the master station and another slave transmitter would provide a second line-of-position, with intersection of the lines fixing platform location.[72]

The first sites included the master station at Balboa in the (Panama) Canal Zone, with the others at Haiku on Oahu in Hawaii and Forestport, New York.[73] Subsequent sites were established by a group of NEL personnel in Wales in 1964 and Bratland, Norway, in 1966. Another site was set up in Trinidad in the West

---

[69] *Fifty Years*, 44.

[70] J.A. Pierce, "The Diurnal Carrier-Phase Variation of a 16-Kilocycle Transatlantic Signal," *Proceedings of the IRE*, Vol. 43, No. 5, May 1955, 584. A decade later, Pierce wrote again on the subject ("Omega," IEEE Transactions on Aerospace and Electronic Systems, December 1965, 200-215), with most of the references cited NEL papers. Pierce served as an NEL consultant on Omega development.

[71] "Omega Long-Range Navigation System; Special Progress Report," NEL Report 958, 1 March 1960, 2.

[72] NEL Command History, 1961, 6.

[73] See: E.R. Swanson, "Electromagnetic Field Strength Measurements at 10.2 Kilocycles per Second," NEL Report 1239, 17 September 1964, 5. This was a report on a study of VLF propagation at a specific frequency, as a basis for predicting the received field strength at an arbitrary location.

Indies in 1969.[74] In late 1968, the Secretary of Defense approved establishment of four new Omega transmitters, which would bring the system to the optimal configuration of eight sites. NEL, collaborating with the Naval Research Laboratory, created Omega systems for aircraft, surface ships, and submarines, enabling them determine location within one nautical mile at night and half a nautical mile in daytime.[75]

Given Omega was a resource "equally useful for all of the world's navigators," the Navy met with representatives of a number of countries to encourage foreign participation and investment.[76] Areas requiring stations were identified as the western Pacific, Tasman Sea, Indian Ocean, and southern South America. When the completed system network was operating effectively, Omega provided a twenty-four-hour, all-weather navigation capability almost worldwide. (Anomalies of radio wave propagation in the high north and south latitudes, based on ionospheric disturbances, provide navigation challenges in those areas.[77])

Throughout its development, during OPEVAL in the early 1960s and formation of a system management office in Washington to coordinate worldwide implementation and that subsequent implementation, the Point Loma lab (as NEL, NELC, and Naval Ocean Systems Center) led development of the technology forming the backbone of Omega. Responsibilities included surface and sub-surface applications, transmitter design and installation, and propagation studies.

At a banquet during the International Omega Association annual meeting in 1979, long-time Center Omega leader Dr. Eric Swanson served as toastmaster. He and others presented papers at the meeting and made speeches at the banquet highlighting the history of the technology. Those will be discussed in Volume II.

As discussed in Chapter 7, a major component of the Naval Air Development Center in Pennsylvania would eventually be merged into the Point Loma Navy laboratory as part of the 1991 Base Closure and Realignment Commission (BRAC) action. Prior to that time, in the mid-1960s, a predecessor organization of NADC was substantially involved in upgrading the Navy's navigation technology

---

[74] NEL *Calendar*, 17 July 1964; April 1, 1966; January 3, 1969.

[75] "Center developed Omega now used in civilian section," NOSC *Outlook,* October 5, 1979, 1.

[76] NELC *Calendar*, January 3, 1969, 1.

[77] B. Burgess, "Some Aspects of the VLF Omega Navigation System as Appropriate to the Arctic Environment," in *Ionospheric Radio Communications* (Boston, MA: Springer, 1968), 91.

capabilities to support requirements of the ballistic missile submarine fleet. John Handal, who ultimately would labor in that area for half a century, worked at both Warminster and in San Diego. Some decades later he would report:

> … they employed us to develop and install and maintain the first satellite transit system that was put on board our 'boomers,' which is the Polaris submarines of the fleet ballistic missiles, and also on the OSP ships… Ocean Survey Program. So that was used for accurate navigation.[78]

Basic research

When he was named NEL technical director in 1961, and throughout his eight years in that position, Dr. Ralph Christensen made it clear he valued basic research. For the next several decades after World War II, those in charge of Navy laboratories at both the working and the secretariat level would debate the expenditure of funds on scientific research versus practical Navy applications. Regardless of the dominance of one or the other faction, it is clear that during the 1960s NEL/NELC personnel conducted some ground-breaking basic science. Some noteworthy examples are described in the following paragraphs:

Sea floor spreading: As detailed in Chapter 6, Dr. Robert Dietz theorized "the fundamental process which creates continents and ocean basins," which he termed "sea floor spreading." His theory describes the sea floor as moving away from mid-ocean rises in opposite directions, pushed by convection forces, piling up "islands" into continents.[79] Over many months and substantial research projects, his theory was proven correct.

Underwater acoustics: Illustrating work with much greater connection to ongoing lab programs, the 1965 Special Honorary Award went to Dr. Homer Bucker for underwater acoustics research resulting in "a pronounced impact on current advanced sonar systems… and an important impact on the design of future systems."[80] Bucker was described as "working in an exceedingly difficult technical area which has baffled experts for years," and recording "a series of unique and

---

[78] John Handal SSC Pacific oral history interview conducted by Tom LaPuzza, December 16, 2014, 1.
[79] NEL *Calendar*, 21 September 1962, 3.
[80] NEL *Calendar*, May 27, 1966, 1.

important developments concerning the effect of boundary conditions on underwater sound propagation."

Dental research: In Chapter 6 there was a similar set of items briefly touching on less mainstream NEL tasking, which included a laboratory "problem" related to dentistry. It need not be repeated here, other than as a reminder such work was going on. No known Center technical publications resulted from this work, but an NELC newspaper story reported the joint retirement of Joseph C. Thompson and Robert K. Logan of the Materials Sciences Lab, about to be phased out. The article reported the two "have been actively engaged in dental research involving denture design" for a decade.[81] Their interesting story is related at the end of this chapter.

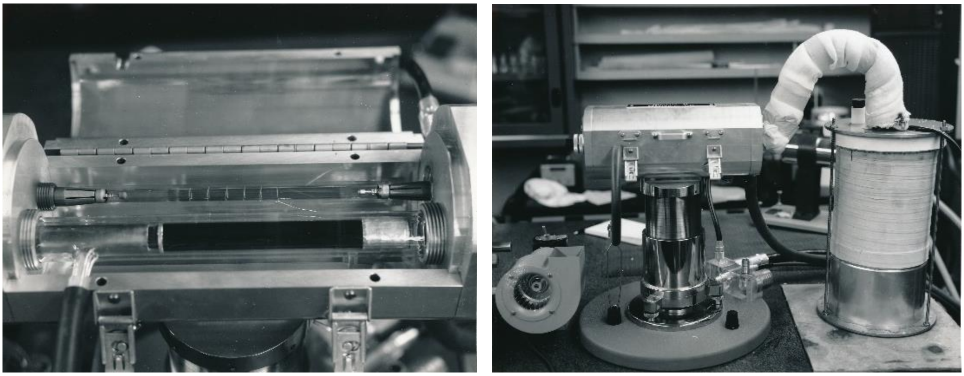
Oceanometrics: Defined as "the application of statistical methods to the vast store of oceanographic data to present it in a form useful to the Navy," Dr. Ernest R. Anderson, who led the NEL effort, elaborated, "Oceanometrics describes that aspect of oceanography concerned with the development of methods and techniques of data summarization utilizing statistical concepts whose application is governed by dynamic considerations."[82] The Naval Oceanographic Office detailed one of its scientists on temporary duty to Point Loma to study the work, resulting in operational programs in several areas, notably underwater acoustics. DoD's National Oceanographic Data Center and the U.S. Departments of Interior and Commerce were also projected to benefit from the NEL foundational work.[83]

Lasers: In the early sixties, NEL began various experiments with lasers—ruby and gas and subsequently liquid, the latter pursued principally by Dr. Erhard Schimitschek.[84] Schimitschek, a Czech native educated in Germany (he earned his Ph.D. in physical chemistry at the University of Munich), arrived in the U.S. in 1958 via the Defense Scientists Immigration Program. He worked several years in private industry, arriving at the lab in the fall of 1962: "I heard about this opportunity to work with solid and liquid lasers at NEL."

As discussed briefly in Chapters 3 and 6, a test pool in the original laboratory headquarters structure, Building A4, was employed in studies of surface ship wakes and submarine camouflage, the latter employing small model subs. No longer required for that, it was drained and filled with construction debris. A laser

[81] NELC *Calendar*, January 31, 1969, 3.
[82] NEL *Calendar*, August 9, 1963, 1.
[83] NEL *Calendar*, August 9, 1963, 1, and February 4, 1966, 3.
[84] "Dr. Schimitschek To Conduct Research on Lasers," NEL *Calendar*, 18 November 1962, 4.

lab was built on top of it. In that lab, Schimitschek and his associates Al Lewis, Richard Nehrich, and Ed Schumacher succeeded in less than a year in developing the world's first liquid laser to produce a visible light beam.[85] Employing a fused quartz cavity .03 inch in diameter he designed, Schimitschek used the rare earth element europium and a ring molecule of benzoylacetonate to produce a cylinder of orange light 6,130 angstroms in wavelength. The design effort earned him the



Provided an appropriate lab, Erhard Schimitschek and his associates successfully developed a liquid laser.

Commanding Officer and Director's Special Honorary Award for 1963, the citation noting he "became the first to demonstrate a visible beam of coherent radiation from a rare-earth chelate in solution."[86]

Somewhat constrained by the required operating temperatures of almost 300 degrees below zero Fahrenheit, Schimitschek later succeeded in developing a similar laser that operated essentially at room temperature.[87] Continued research resulted several years later in a procedure to recirculate the laser's chemical liquid mixture, allowing substantially higher pulse rates.[88]

Reflecting the philosophy of the technical director at the time, a *Calendar*

[85] One of the reviewers of this history pointed out, reasonably, that the technical literature cites others as "the first" for this significant achievement. He also provided a citation lending credibility to that claim: "Stimulated emission in rare-earth chelate (Europium benzoylacetonate) in a capillary tube," *Applied Physics Letters*, Vol. 3, No. 7, 1 Oct 1963, 117.
[86] NEL *Calendar*, 22 May 1964, 1. See also *Calendar* of 1 November 1963, 1.
[87] NEL *Calendar*, 18 September 1964, 2.
[88] NEL *Calendar*, January 14, 1966, 1.

article reporting the discovery stated it was "not directed toward possible application. Here the goal is the basic research why a laser works, and how."

Schimitschek would continue his pioneering laser research, with several associates, for decades. It would result, as will be related in Volume II of this history, in his reception of the first Naval Ocean Systems Center Lauritsen-Bennett Award for Science and his selection for the Demonstration Project's first DP-V.[89]

Another laser project, "still so new to the technical field that there are only four others in the United States," was the spin flip Raman laser. Dr. Steve Miller, who directed the exploratory research, reported the interest was in using the laser as a communications transmitter.[90] Miller and his associates Dr. Cedric Gabriel and Dr. William Schade employed a carbon dioxide gas laser to pass a beam of infrared radiation through a semi-conductor crystal in a magnetic field. The strength of that field could be varied, allowing tuning of the output: "What we have is a laser which can be tuned to any desired wavelength by the mere flip of a knob."

In addition to the effort to build a compact laser for a ship communication system, they noted the device potentially could detect air pollution levels.

Additional basic research of the era involved VLF/ELF (extremely low frequency) radio frequencies, elevated duct radio wave propagation, and deep ocean research. A newspaper article of the period reported on extensive undersea studies undertaken by NEL scientists employing the manned undersea vehicle *Deepstar*, which was leased from Westinghouse for a ten-month period of research dives. Kenneth Mackenzie, who headed the lab's Deep Submergence Group and was chief scientist for its deep submergence program, compared the work done with *Trieste*, for which he was also responsible, and *Deepstar*:

> We'll probably have a continuing program with intermediate depth, small vehicles to supplement our studies using the large craft. The smaller submersibles are especially suitable for exploring continental slope areas and canyons where efficient bathyscaph operations are not possible.[91]

---

[89] NOSC *Outlook*, January 12, 1979, 1, and March 6, 1987, 2. The Demonstration Project/Alternate Personnel System was established in 1980 as the first congressionally authorized project for improving the traditional General Schedule (GS) form of personnel management and pay which had caused the Navy laboratories such difficulties over the decades in classifying, hiring, and retaining top scientists and engineers. In that project, a DP-V (Demonstration Professional Level 5) equated to a GS-16-18, or a Public Law/Senior Executive Service (SES) position.

[90] NELC *Calendar*, March 2, 1973 1.

[91] "The Deep Submergence Story," NEL *Calendar* Special Edition, June 24, 1966, 1.

The work of a dozen lab scientists was also summarized, including:

Marine geologist Dr. Edwin Hamilton, who intended to "determine realistic acoustic models of the sea floor by measuring and studying the velocity and attenuation of sound and associated physical properties in the upper regions of sediments."

Biological oceanographer Dr. Eric Barham, whose four-phase research included biological observations and underwater acoustic measurements.

Vietnam Laboratory Assistance Program

A fairly non-typical "project" surfaced in 1965, with establishment of the Vietnam Laboratory Assistance Program (VLAP). As was probably reasonable, a leadership role was given to China Lake, which had begun its unprecedented development of weapons for the expanding combat in southeast Asia. (As an unparalleled example: "Eighty percent of the weapons dropped in Vietnam were developed at China Lake."[92])

The general concept behind the program was that military personnel in a combat zone often experience minor challenges with their equipment, ordnance, etc. that, given the usual bureaucracy, would take years if not decades to resolve. However, designating specific technical personnel from the Navy laboratories, essentially representing *all* the labs, might provide a near-immediate solution to the problem, such that the troops could move forward to accomplish their missions in a timely fashion. According to an NELC newspaper article,

> The program, known as Vietnam Laboratory Assistance Program (VLAP), was initiated by Director of Navy Laboratories over a year ago in an effort to provide more direct laboratory support of the Navy's fighting men and to keep Navy laboratories better informed about needs, conditions, and operation of equipment in the field.[93]

One of the Point Loma laboratories' early volunteers for VLAP made an interesting observation: "To conduct riverine warfare the Navy has had to build a small boat navy—something we haven't had since the Civil War. Working with

---

[92] Quote attributed to Secretary of Defense Robert S. McNamara. *The Station Comes of Age*, 245.
[93] NELC *Calendar*, March 8, 1968, 1.

new situations means solving new problems and that's primarily what we're doing…," said Irv Olson, who had just returned from a four-month tour in Vietnam.[94] NOTS China Lake actually had come up with a potential solution to that problem a year or so before VLAP formally commenced: the Patrol Boat, River (PBR). While one China Lake team supported the concept of populating the Mekong River with floating versions of a tank, another suggested "a very lightweight, fast, maneuverable, heavily armed patrol boat that could get into tight places but have enough firepower and enough speed to get out. And that led to the PBR."[95] NELC's Irv Olson, who served his Vietnam tour from late 1967 to early 1968, worked primarily in the area of communications, particularly improving those required by the PBRs.

When the assistance program came into being, engineers from San Diego and China Lake generally spent three to four months in-country, a third or a half of that time usually trying to convince military personnel they were actually there to help. As time went on, however, and each new lab representative built on the success of the previous, the relationship improved, and the lab engineers were able to contribute more and better solutions. One example addressed by the San Diego electronics lab related to problems caused by a radar scope: the night vision of small boat operators was impaired by light emitted from the radar scope. NELC designed and provided about 200 variable intensity polaroid filters for river patrol boats. The prototypes were in the field two months after the first request.[96]

China Lake contributed a wide variety of solutions for problems experienced by the military in Vietnam, ranging from water transportation containers to an aircraft radar beacon, a portable low frequency radio set, and flak suppression devices.[97]

The concept of direct support of the military in combat operations or similar circumstances outlived the specific war in which it originated; in 1972, VLAP became the Navy Science Assistance Program. (See Chapter 13.)

---

[94] NELC *Calendar*, March 8, 1968, 3.

[95] *The Station Comes of Age*, 274.

[96] "Polaroid filters for small boat radars meet urgent Vietnam need," NELC Command History 1968, 7 Aug 68, 1.

[97] *The Station Comes of Age*, 284.

Facilities

Operating as they were on the cutting edge of technology, the California Navy labs often were obligated to contract for special equipment or facilities in order to meet sponsor requirements. Even more frequently, they designed and built their own. In San Diego, the 1960s saw construction of critical facilities for microelectronics research (described above) and underwater acoustics, plus an at-sea platform for general ocean research.

Transducer Evaluation Center

Loss of a testing resource dating back to the Point Loma lab's World War II underwater acoustics research resulted in development first of a model, and then a full-scale "transducer calibration tank."[98] Charles Green, a counselor for San Diego City Schools District until World War II prompted him to return to classes at UCLA for a physics degree, was one of a number of lab technical personnel making use of the transducer calibration facility at Sweetwater Lake. When facility owners lowered the water level, Navy continued use of it became marginal, then impossible. Green sought an alternative. After a search for an appropriate body of water proved unsuccessful, he conceived the idea of designing his own, one that would specifically meet NEL transducer testing requirements and at the same time eliminate the necessity of seeking unreliable lakes and reservoirs for underwater acoustics experimentation and calibration. He fashioned a 30-to-1 scale model out of plaster (after initial fabrication of a smaller version using modeling clay) and demonstrated the utility of the concept.

Construction began in 1962 on the Transducer Evaluation Center (TRANSDEC), with a hard-hatted Green directing bulldozer operators in precision cutting of bowl-shaped features in the Point Loma landscape within tens of yards of Cabrillo Memorial Drive, in preparation for pouring thousands of yards of concrete. The final result was an elliptical pool 300 by 200 feet, 38 feet deep at the center, with a circular concrete bowl in the middle. It held 5.6 million gallons of fresh water. As Green explained in a technical report, "The bottom of the pool

[98] NEL *Calendar*, 13 May 1960, 2.

and the air-water interface serve as reflectors… the pool is shaped to trap acoustic rays traveling from the transducer in any direction."[99] The structure design eliminated reverberation, allowing precise calibration of sonar transducers in a dedicated facility a few minutes' drive from NEL headquarters. (The drive to Sweetwater Reservoir was twenty-six miles, each way.) Green's project description stated:

> 1. An anechoic pool was designed and built to behave as an infinite body of water.
>
> 2. A computer and associated equipment were provided to permit complete analog evaluation of transducers of normal frequency range, size, and weight.
>
> 3. A bridge was constructed to house equipment and personnel and to isolate them acoustically from the water.


Lacking appropriate testing facilities elsewhere, Charles Green designed and managed construction of his own Transducer Evaluation Center on Point Loma, less than a mile from the NEL headquarters building.

The latter was essentially a pre-World War II British invention called a Bailey Bridge; it was placed directly over the TRANSDEC pool, providing a walkway for engineers and technicians, a platform for instrumentation equipment to conduct sound studies, and a stand for a crane to lower transducers under test into the water. Anchored by uprights on each side across its short axis, at no point was it in contact with the pool itself, thus eliminating both acoustic energy and vibration.

[99] C.E. Green, "Acoustic Transducer Evaluation Center (TRANSDEC)," NEL Report 1232, 24 August 1964, 6. See also: NEL *Calendar*, 10 and 17 July 1965, and SSC Pacific 75th Anniversary *News Bulletin*, 64.

The facility was dedicated July 10, 1964, enabling extremely accurate evaluation of transducers for ASW weapon systems and countermeasures, and for mine hunting.[100] In early January 1965, Green was presented a presidential citation for economy improvement, based on the calculated $76,000 in first-year savings with operation of TRANSDEC.[101]

Oceanographic Research Tower

A highly visible and enduring laboratory structure, used extensively in the 1960s and substantially beyond, was located not on Point Loma but in sixty feet of water a mile west of the popular Mission Beach. The Oceanographic Research Tower was a shallow-water platform that included small laboratories and scientific instruments for studying the sea, plus makeshift eating and sleeping facilities for required overnighters. The tower perched on four sixteen-inch steel legs, driven sixty-three feet into the ocean floor at an angle, a foundation stable enough to withstand the forces of nature for more than thirty-two years.[102]

One of several significant innovations of Eugene LaFond, the tower was "the first stationary sea-based facility designed and used exclusively for investigating a wide variety of shallow marine environmental features," according to an early report.[103] The location offered scientists an opportunity to perform "a wide diversity of studies… water motion, underwater acoustics, electromagnetic propagation, marine chemistry, marine biology, and marine geology. It also serves to test and evaluate newly developed techniques and equipment." It provided laboratory-like conditions of stability, quiet, extensive instrumentation, and a constant power supply for shallow-water research in the open sea. (And "open" is literal: located only a mile offshore, it was not enclosed by a harbor or bay of any description, and the closest piece of land on a line absolutely due west was somewhere on an island in Japan.[104]) Electricity was brought by cable from the

[100] NEL *Calendar*, 10 July 1964, 2.
[101] NEL *Calendar*, January 8, 1965, 1.
[102] Naval Ocean Systems Center *Outlook*, January 22, 1988. Also, *Fifty Years of Research and Development*, 40.
[103] E.C. LaFond, "The U.S. Navy Electronics Laboratory's Oceanographic Research Tower," NEL Report 1342, 22 December 1965, 7.
[104] Admittedly, that absolutely straight line was about five miles south of the southwestern edge of San Clemente Island, at 32.771 vs. 32.801 degrees N.

shore, avoiding the noise and vibration from an onboard generator and enabling steady voltages and frequencies for sensitive recording equipment. Installed vertical railway tracks on three sides of the tower permitted instrument carts to be positioned at any level above or beneath the water surface for data collection. That environment enabled extensive *in situ* research: "In the waters surrounding the tower, there were approximately 150 temperature sensors, wave height sensors, and transducers hardwired to onboard instruments. Five arrays of thermistor beads continuously monitored the water thermal structure. Other equipment recorded, wave motion, current speed and direction, sound velocity, and water clarity."[105]

One obvious problem with experiments at sea is the inevitable ship motion in three dimensions. On the motionless tower, sensitive optical, acoustic, and chemistry instruments could operate to their full potential. Although from shore the tower looked something like an offshore oil drilling platform, onboard the work environment was more like that of a high-tech laboratory. Located conveniently just thirty minutes' travel time by car and boat (operated by lab military personnel) from NEL, the Oceanographic Research Tower was situated away from heavy commercial shipping lanes and thus provided a relatively undisturbed marine environment, an attractive factor for scientists and engineers studying electromagnetic and acoustic wave propagation and the behavior of seawater itself.

An acrylic plastic sphere similar to those on Center underwater manned vehicles was installed at the tower in the early 1970s (when "ownership" had switched from the electronics organization to the undersea center). It allowed a pilot and one observer to descend to the sea floor sixty feet down, providing an unlimited-view platform for marine-life observations.[106] The tower hosted a variety of Navy lab shallow-water studies until it was transferred to Scripps Institution of Oceanography in 1986. Two years later, a January storm brought it down; since then it has been a popular diving spot.

"Big Charlie"

In his report on the Transducer Evaluation Center, Charles Green stated, "TRANSDEC is not a cure-all for every calibration need and is not a substitute for

[105] *Fifty Years of R&D*, 40.
[106] Naval Undersea Center *Seascope*, August 18, 1972, 1.

the NEL calibration station on Lake Pend Oreille, which remains the Navy's principal deep-water calibration facility for large, high-power, low-frequency transducers."[107]

As noted in Chapter 6, NEL had established an underwater test range at the Idaho lake in the early 1950s. As the range's work expanded, larger "facilities" were required, and NEL's only physical plant items were on the surface of the lake itself. Consistent with the increased work load, Green designed and supervised construction of a hundred-ton self-propelled barge. It included a thirty-by-sixty-foot main operations building and two twelve-by-sixteen-foot auxiliary buildings, and was equipped with a complete SQS-23 sonar system. Hoists aboard the barge could easily move ten-ton loads; two A-frames were able to move loads up to a hundred tons.[108] In February 1966, "Big Charlie" (It was *not* named for Green) passed its test run at the lake and began several decades supporting development and evaluation of sonar transducers and systems, which will be discussed later.

NOTS programs

Earlier in the chapter, it was reported an NEL communications engineer appeared somewhat anomalously at an anti-submarine warfare conference at the lab to speak on the subject of communications research. The vast majority of the speakers at that conference did in fact discuss topics related to ASW. Four of them were NEL associates of Peter Duncan, while another five were on hand representing the Naval Ordnance Test Station and its weapons development programs at China Lake and Pasadena.

While the woeful state of the facilities at Pasadena has been given substantial coverage (and doesn't need any more), an important reality is that the engineers and scientists and technicians were not influenced materially by their surroundings. The facility shortcomings may have resulted in more work (or more work-arounds), but the fact remains that the work was being accomplished and was meeting the requirements and expectations of sponsors. Norm Estabrook's previously cited comment about Pasadena as a "dump" and "an old orange crate

---

[107] C.E. Green, "Acoustic Transducer Evaluation Center (TRANSDEC)," NEL Report 1232, 24 August 1964, 28.
[108] NEL *Calendar*, February 25, 1966, 1.

factory" was followed up with a much more encouraging: "… but I saw past that and I saw the work that these people were doing."[109] In interview after interview of long-time station employees, a reasonably negative beginning to a sentence ("Of course, it was the lowest-paying job offer I got") was reversed based on "but I took it because the work looked so interesting."

That intriguing combination of inadequate facilities and technical personnel seeing beyond appearances and austerity to provide the Navy with new weapons is what the Pasadena Lab of the Naval Ordnance Test Station was all about, following doggedly in the footsteps of its parent at China Lake, born of searing desert heat and blinding sandstorms, substandard housing, and lack not only of the comforts of home, but often even the necessities.

Despite the many shortcomings forced by their environments, personnel at China Lake and Pasadena had spent two decades developing an impressive array of weapons for the Navy, foremost among them the submarine-launched Polaris missile, the Sidewinder air-to-air missile, and the Anti-Submarine Rocket. The decade of the sixties featured a number of refinements and improvements of Sidewinder, including an updated version with a similar infrared seeker head and another which replaced it with radar guidance. Other variants initiated, dubbed "Sons of Sidewinder," were Subwinder, an undersea launched version that never got beyond early testing, and Project Hamburger, a surface-launched infrared and radar-homing version for gun mounts.

These various upgrades were of substantial value, but admittedly the original was in a class by itself. The most obvious reason, of course, was no similar weapon was even comparable. In four decades of service, Sidewinder accounted for at least 270 aircraft kills, a record not even approached by any other air-to-air missile.[110] Of nearly equal importance was the philosophy under which it was developed, perhaps unique to China Lake. Taking advantage of "a set of circumstances—co-located laboratories, ranges, restricted airspace, machine shops, propulsion and explosives facilities, specialized test complexes, an airfield—that could not, and had not, been duplicated anywhere," the China Lake team demonstrated an unusual ability to compete vociferously when circumstances dictated, and then an equivalent tendency to cooperate unselfishly when the need arose:

> Sidewinder was zealously protected by China Lake management—not infrequently, in the case

---

[109] Norm Estabrook Naval Weapons Center interview conducted by Leroy Doig III, 9 August 2011, 1.
[110] *The Station Comes of Age*, 382-3.

> of military officers, at the expense of further career advancement—from a Washington bureaucracy that often lacked vision, abhorred independent action by field activities, and resented the Station's ability to juggle its finances to support worthwhile projects."[111]

Clearly the close proximity and culture of interaction between the military pilots who would use a weapon and the weapon designers was invaluable in the development process.

The rule of cooperation, of course, was not without exceptions. As was reported earlier in the discussion of the Anti-Submarine Rocket, Underwater Ordnance Department head Doug Wilcox went to great lengths to maintain a close working relationship between those on his team at Pasadena and those at China Lake. Unfortunately, such a working relationship was not always achieved on other projects, and while there may have been other reasons for that, the key one was fundamental to the two locations' working philosophies:

> The two different approaches to weapons development taken at China Lake and Pasadena reflected those taken by the Bureaus of Ordnance and Aeronautics. China Lake, like BuOrd, tended to maximize the use of in-house resources right up to the point of production. Pasadena, like BuAer, had earlier and deeper dependency on the services of the private sector.[112]

The NOTS commander (P.D. Stroop, one of only three officers from the Navy laboratories in this history to achieve flag rank while on duty at that command), recognizing the intricate and potentially troublesome relationships between the bureaus, the station, and various contractors, requested a management philosophy be developed to serve as a focal point for maintaining an equitable working environment with and for all concerned. While substantial input was provided for the resulting document by the three development departments at China Lake, the Underwater Ordnance Department, the only one at Pasadena, appears not to have been even asked for thoughts on the subject. Seemingly the final document reflected the philosophy of Technical Director Dr. William McLean, his deputy, and his China Lake senior management, without concern for Pasadena interests.

---

[111] *Station*, 383.
[112] *Station*, 430.

Poseidon

Chapter 8 provided substantial detail on the combined China Lake-Pasadena essential contributions to the Navy's submarine-launched fleet ballistic missile program. A decade later, the third issue of the NUWC Pasadena newspaper printed a front-page story, "This Week Marks Tenth Anniversary of Polaris."[113] More than a historical recounting of an important past event, the article also reported a comparably important event had occurred seven months earlier—the first underwater launch of the Polaris successor, Poseidon, at the San Clemente Island test range.

President Lyndon Johnson had announced the start of the Poseidon program in a special address to Congress in January 1965. The Special Projects Office had designed the Poseidon C3 missile twenty inches larger in diameter, three feet longer, and fifteen tons heavier than Polaris. Nevertheless, with certain fairly straightforward modifications, the Poseidon missiles were compatible with launch tubes on the Polaris boats. With an all-inertial guidance system, a solid-propellant gas generator, and a range of 2,500 nautical miles, Poseidon's major claim to fame was the ability of each missile to carry up to fourteen Multiple Independently targetable Re-entry Vehicles (MIRVs). In essence the weapon, once launched from deep underwater and projected high into the air, could deliver accurately fourteen potent warheads to fourteen different, widely spaced targets (or several to the same high-value target).

As it had for Polaris, the Pasadena Lab and its SCI test facility would provide the Pop-Up Range for a series of tests, initiated August 2, 1967, and contribute to the development of procedures to ensure the successful transition from missile tube to the open sky. Recognition for substantial contributions to that testing came in the form of a Poseidon flag to fly over the Pasadena Laboratory.

During the time period under discussion (basically the 1960s), engineers at China Lake initiated a series of missile, rocket, and space projects that are outside the scope of this discussion. While those early space efforts were important, the oceanographic/undersea vehicle focus was significantly near and dear to McLean, who loved the ocean and everything about it, and stated time and again it was where the future of the Navy resided.

[113] Naval Undersea Warfare Center *Seascope*, March 22, 1968, 1.

Mark 46 torpedo

The advent of jet aircraft and guided missiles substantially altered the air warfare environment, stimulating development of the Naval Tactical Data System with essential leadership and technical contributions by NEL. In a comparable manner, advent of faster, deeper-diving, nuclear-powered submarines, many equipped with ballistic missiles, drastically altered the field of ASW, for which weapons were developed by NOTS Pasadena. Although Pasadena Lab projects like the Anti-Submarine Rocket and the testing of all three submarine-launched fleet ballistic missiles generated extensive national and international headlines, there is indisputably no weapon system longer lived or more ardently worked by the lab than the anti-submarine warfare torpedo Mark 46.[114]

As discussed in Chapter 7, NOTS Pasadena had a key role in resurrecting the Mark 32 torpedo, on which development had been initiated and then halted during World War II, and getting it into the fleet. That success provided a solid foundation for Pasadena engineers and technicians to launch into the torpedo business. That particular business, as stated earlier, is mainly reactive: the torpedo, to succeed, must be approximately fifty percent faster than the target for which it is intended. As the 1950s moved into the '60s, the U.S. and the Soviet Union played off each other, both nations building faster and deeper-diving submarines while simultaneously working to counter the other's with faster torpedoes.

While the German WWII diesel sub which the Mark 32 countered had a speed of eight knots, post-war Soviet subs could steam eighteen knots, setting the required speed for the Mark 44 torpedo at thirty knots. Translating USS *Albacore* (AGSS-569) design speed to projected emerging Soviet nuclear boats, "… that's where the requirement then became—they picked the number 46 knots as the next step…," explained long-time Center torpedo developer Mort Heinrich.[115]

The Mark 44 had begun as the experimental EX-2 torpedo under the Research Torpedo Configuration (RETORC) program, initiated in 1954 by the NOTS Underwater Ordnance Department. The final design included electric propulsion.

---

[114] To illustrate, the cover of a summer 2012 issue of U.S. Naval Institute *Proceedings* featured a color photo of the launch of a Mark 46 Mod 5 torpedo the previous November, forty-five years after fleet introduction of the initial version. Given that longevity, NOTS, NUWC, NURDC, NUC, and even the Naval Ocean Systems Center worked on Mark 46.
[115] Mort Heinrich SSC Pacific oral history conducted by Tom LaPuzza, June 20, 2012, 19.

For the RETORC EX-8, which became the Mark 46, Pasadena designers had determined to switch from electric propulsion to a hot-gas pump-jet engine using solid rocket fuel. For its substantially longer range in target acquisition, Mark 46 was configured with two different acoustic panels for sonar processing: LANA, a transistorized panel using a frequency modulation pulse, and REVEL (REVerberation ELimination), employing a narrow frequency system and filtering to eliminate echoing and increase the sonar's detection range. The latter was the invention of Pasadena electrical engineer Dr. Jack Slaton, for which he received the prestigious NOTS L.T.E. Thompson Award in 1962. (Slaton's boss Chuck Beatty received the award in 1964 for his overall management of the Mark 46 program.) Slaton's ingenuity in torpedo design garnered substantial recognition over many years working at the Pasadena Lab and later in San Diego.[116]

As reported in the Center's fifty-year history, "The most significant research and development that went into the Mk 46 was the REVEL guidance system. Until the REVEL system…, torpedo guidance had not changed appreciably since World War II."[117]

A Mark 46 torpedo was eight feet, five inches long and just under thirteen inches in diameter, weighing 570 pounds. Simplifying maintenance, four major component sub-sections—guidance and control, explosive, propulsion and accessory—could be replaced as single units.[118] The weapon could be launched from every Navy platform: submarines, surface ships, fixed-wing jet and propeller aircraft, helicopters, drones, and rockets. With the noted dual sonar search and guidance methodologies, it could locate a deeply submerged submarine whether the target was hovering motionless near the bottom or running all ahead full. Its speed of 46 knots was particularly important, because the sound of its active search sonar warned target submarines of its approach, so a "chase" was likely.

The determination had been made early on that NOTS, specifically the Underwater Ordnance Department, would be technical director for Mark 46, with major development responsibility handled by a prime contractor and two lesser industrial partners. (In its director role, NOTS would not only design and support

[116] More than two decades later Slaton was presented, with co-designers Bob Marimon and Bob Mathews, invention awards amounting to more than $11,000 on five torpedo patents, the largest such award since the establishment of NOSC. NOSC *Outlook*, August 26, 1983, 1.
[117] *Fifty Years of R&D*, 87.
[118] *The Station Comes of Age*, 441.

Air-drop test of a Mark 46 torpedo from an ASW aircraft off San Clemente Island to ensure proper break-away of restraining clamps and parachute deployment.

development of the torpedo, but also keep close tabs on the contractor during manufacturing, support fleet introduction, and continue to maintain and improve it during its operational service life.) Major difficulties requiring substantial attention by program manager Chuck Beatty and project engineer Mort Heinrich were glaring cost overruns and contractor "tinkering" with the NOTS design. The former, as noted by Dr. William B. McLean some years later, was a prime example of the failed system that provided the lab responsibility for technical monitoring without authority to control the funding.[119]

The assistant chief of the Bureau of Naval Weapons for RDT&E (and NOTS commander 1955-57) did not mince words in his assessment of those involved:

> We had a terrible time with [the contractor] because they wanted to fix everything all the time. They wanted to change this and change that and change the other thing. And the people down at Pasadena knew more about torpedoes than Aerojet-General had ever heard of. I think Pasadena's forgotten more than they ever knew... Finally I got to the point where I went out there. I said, 'Look, if you don't do it our way, we're going to take this contract away from you.' I don't know whether I had power enough to do it or not.…"[120]

Responding somewhat in parallel to that, project engineer Mort Heinrich insisted on what was contracting heresy, demanding

> the authority to sole source the development of the subsets using our engineers, their capability for design and modification packaging of the electronics… I want to be able to contract with them directly… I got deals to go develop the Mark 46 Mod 1… to upgrade the capability of the torpedo using the best parts of Mark 46 Mod 0, but fix the engine to get away from the solid propellant that they use in the Mark 46 Mod 0.[121]

After the Mark 46 was released to the fleet, NOTS engineers and technicians continued to improve the torpedo. One of those was employed in an actual live firing in late 1969, with the target the decommissioned submarine ex-USS *Burrfish* (SSR-312). Launched from an SH-3 helicopter off San Clemente Island, the torpedo sank the underway (remotely controlled) sub in a spectacular geyser of water.

Hydroballistics modeling

While much of the torpedo development effort was mechanical engineering coupled with control system technology, basic science was also involved. Combining theory and experiment, Dr. John Waugh for years used the Pasadena vertical water tunnel to conduct research in hydroballistics modeling of torpedoes

---

[119] Dr. William B. McLean, Naval Weapons Center interview S-97 of 1975, 29.
[120] Vice Admiral Frederick L. Ashworth China Lake interview, 16-17 April 1993, 136.
[121] SSC Pacific contractor interview with Mort Heinrich, December 16, 2014, 11-12.

The decommissioned USS *Burrfish* (SSR-312), underway and remotely controlled, was sunk by a lethal Mark 46 torpedo.

and water-launched missiles. In lengthy reports, he described the multiple forces at work in what seems a simple act of a missile entering the water: gravitational forces, water density and motion, gas bubbles forming on water entry, angle of entry, shape of the water cavity formed by missile entry, shock waves in the missile… the list goes on and on.[122] Over time, Waugh and his coworkers amassed a wealth of knowledge directly applicable to designing better torpedoes and understanding their behavior under every condition.

[122] John G. Waugh et al., "Hydroballistics Modeling," NUC TP 447, January 1975. Earlier, Dr. Waugh and his associate G.W. Stubstad had written an exhaustive technical volume with the same title, published by the Naval Undersea Research and Development Center in 1972.

Undersea vehicles

In November 1965, the Pasadena Lab invited a gaggle of news media aboard to reveal the Navy's first manned deep-ocean craft—*Moray* and *Deep Jeep*. Their host, NOTS TD Dr. William B. McLean, explained to reporters that for the first time the Navy had a capability to do meaningful tasks underwater, presenting films to demonstrate these new and unusual devices under actual operational conditions.

Moray had the appearance of a giant torpedo, thirty-three feet long and sixty-four inches in diameter. Fashioned of fiberglass laminate as streamlining for the spherical cockpit, the latter was the pressure hull for two pilots, and was configured substantially like an airplane cockpit, including some of the identical instrumentation. The operators had an "automatic pilot" feature that allowed them to set a course and heading, which the submersible followed. At the time of the press conference, the vehicle had been tested to depths of 2,000 feet off San Clemente Island.

The vehicle was conceived as a joint effort of the West Coast ASW Laboratories, consisting of NOTS, NEL, Scripps, and the University of Washington Applied Physics Lab.[123] McLean, always the ocean enthusiast, was an active participant in the discussions and followed up discussion with assignment of vehicle design and development responsibilities to his engineers.

According to the station history,

> Next to the Sidewinder missile, Moray [sic] may have been the NOTS development program closest to McLean's heart. He agreed, and argued persuasively, that the future of the Navy lay not on top of the ocean but under it… He was convinced that the world's ocean depths offered endless possibilities for the Navy as well as for civilian habitation, recreation, and commerce.[124]

Originally conceived as a two-man high-speed submersible carrying rockets,

---

[123] The Navy, particularly after the World War II success of military-academic cooperation, contracted with hundreds of universities and their laboratories for a wide variety of scientific endeavors. In addition to those individual efforts, the service contracted extensively, in areas of significant importance, with four: University of Washington Applied Physics Lab, Johns Hopkins Applied Physics Lab, University of Texas Applied Research Lab, and Penn State Applied Research Lab. In the 1990s these four labs became DoD University Affiliated Research Centers (UARCs), managed by the Navy under sole source contracts.

[124] *Station*, 459.

Moray was designed to hunt down and destroy submarines, obviously a mission highly classified at the time. It was billed to the news media: "Moray [sic] was designed to operate as an undersea laboratory device to a depth of 6,000 feet, at 15 knots, guided and controlled by its two-man crew."[125] The *Rocketeer* version, which one assumes was quoting from the same press-release material provided to the reporters at the news conference, continued: "The current task set out so far for Moray to accomplish is the location, identification, and classification of underwater objects with the aid in development of underwater television, radio communications, sonar and sound localization techniques."

(In an upcoming discussion of the Marine Mammal Program [Chapter 11], we will relate that the animals perform "underwater surveillance for object detection, location, marking, and recovery." In both instances, the remarkably similar formula adopted to avoid security breaches in fact described the purpose of the technology absolutely accurately, merely omitting the specific targets of those efforts.)

Regardless of its specific tasks or related security, the fact remained that *Moray* was the first research vehicle designed, built, and tested for manned deep-sea operations by the U.S. Navy or, for that matter, by anyone. (An obvious exception is the bathyscaph *Trieste*, purchased by the Office of Naval Research and assigned to the Navy Electronics Laboratory. Substantial difference is *Trieste* essentially functioned in a sense almost as an "elevator," dropping straight to the sea floor and then ascending straight to the surface, its lateral movement based primarily on uncontrollable action of waves and currents. It did have the ability to move a short distance underwater, but it was not intended to move about freely and conduct "operations.") It could reasonably be viewed as the opening venture into inner-space exploration that would soon explode, not only for the Navy, but eventually for industry as well. As might be expected, Bill McLean was the creative spark that ignited it and the driving force that moved it forward.

At the same Pasadena news conference, an ungainly looking contraption called *Deep Jeep* was unveiled, its practical application the recovery of ordnance at the bottom of underwater ranges and exploration of deep underwater canyons. Managed by Will Forman, who would subsequently be regarded as one of the pioneers in manned underwater vehicles, it was launched near Santa Barbara in January 1964, a five-foot-diameter spherical steel vehicle weighing four tons. Early testing demonstrated it could cruise at a speed of two knots and descend to a

[125] NOTS *Rocketeer*, November 12, 1965, 1.

depth of 2,000 feet, able to hover at a desired depth with precision. It provided adequate air supply for dives of four to six hours.[126]

Both *Moray* and *Deep Jeep* were originally developed in the desert, tested in such unlikely places as the Supersonic Naval Ordnance Research Track (SNORT) braking reservoir. When the appropriate time for ocean testing occurred, the likely venues were the Long Beach and San Clemente Island facilities managed by NOTS Pasadena, which itself was delving into the underwater vehicle area.

CURV

While *Deep Jeep*'s development had been for the general purposes of "undersea exploration" and "ordnance recovery," there were no specific targets for such purposes, especially at China Lake. On the other hand, Pasadena engineers and technicians were on the Long Beach and San Clemente Island test ranges daily, launching torpedoes which often required recovery from the sea floor.

In the early days of at-sea testing, a recovery "system," consisting of a barge equipped with several grappling devices, provided a burdensome and inefficient means for accomplishing that task. Seeking, as always, a better approach, Pasadena personnel had acquired a vehicle developed by a contractor that demonstrated some possibilities, although they were far from adequate. They took it apart and rebuilt it with almost entirely new equipment—thrusters, sonar, TV cameras. Rather than a title, they provided the refurbished platform a descriptor of its essence and its purpose: Cable-controlled Underwater Recovery Vehicle (CURV). It was the first in a long line of undersea vehicles the lab would develop and field. Had it not responded convincingly to a catastrophic disaster early in its career, it might have been merely another one of them. Its moments of intense public interest will be described in detail in Chapter 12.

SEALAB

The CURV devices, controlled by topside operators, were effective at locating

[126] NOTS *Rocketeer*, November 12, 1965, 5.

and retrieving objects and at exploring and photographing deep or otherwise dangerous environments for humans. But the national spirit of the 1960s kept returning to human exploration of space and sea. In 1976, long-time Center ocean engineering leader Howard Talkington wrote a report stating,

> A flag could be planted on top of Mount Everest by dropping it from an aircraft… [but] to set the flag at the summit after having scaled the heights of the icy mountain, that is the supreme satisfaction, the supreme accomplishment. This is the glory of a goal personally attained. That man is a searching, conquering, proud being must be taken into account: because this conviction affects the thinking of everyone who establishes goals for an undersea project, especially those who always insist that man must be present at the work site.[127]

And while NASA sent astronauts in ever-longer orbital missions, with an eventual goal of a moon landing, the Navy, including NEL and NOTS, continued its SEALAB underwater living experiments off the coast of La Jolla, California, as an integral component of its Man-in-the-Sea Program.[128]

SEALAB II was an underwater habitat and laboratory fifty-seven feet long and twelve feet in diameter. Between August and October 1965, it hosted three ten-man teams, the first two led by astronaut-turned-aquanaut Commander M. Scott Carpenter. Located in La Jolla Canyon a short distance from the Scripps Institution of Oceanography pier, at a depth of 205 feet, it was equipped with meters to measure current, temperature, water clarity, and bioluminescence, as well as external television cameras and diving lights. The prime purpose of the project centered on the aquanauts themselves. While submarines approximate above-the-surface conditions within their pressure hulls, SEALAB was more attuned to its environment: divers' bodies were "pressurized" on the surface, in the transfer capsules, and in the habitat itself, decompressing only when they returned to the surface after their two weeks underwater. They ventured regularly from the habitat into the frigid water, testing new suits and equipment. They conducted numerous physical and psychological assessments, taking daily measurements of physical dexterity and mental acuity, and collecting blood, urine, and saliva samples. The second team worked with a NOTS dolphin named Tuffy (see Chapter 8), who, in demonstrations of various capabilities, brought mail and tools

---

[127] Howard R. Talkington, "Manned and Remotely Operated Submersible Systems: A Comparison," Ocean Technology Department, Naval Undersea Center, June 1976, 9.

[128] SEALAB I, an eleven-day mission conducted in July 1964 with four Navy divers off the coast of Bermuda, was conducted to test basic technologies and establish safety measures for underwater habitation. As noted in Chapter 8, SEALAB is the "official" version of the various renderings, which include SeaLab, Sealab and Sea Lab.

from the surface and carried recovery lines to “lost” divers. Given the nature of saturation diving, a diver who was actually lost probably would have died if forced to surface, so that capability was a critical one.[129]

SEALAB II produced a wealth of data, and, after its conclusion, the Navy determined to continue undersea experimentation with an even more ambitious effort. SEALAB III, using the same habitat with some improvements based on experience gained in the previous experiment, would be sited at the much greater depth of 600 feet off the San Clemente Island facility of the newly established Naval Undersea Warfare Center. NUWC, headquartered in Pasadena and with a contingent of oceanographic and sonar personnel in San Diego (previously part of NEL), played a major role in SEALAB III. The third issue of the Center’s brand-new publication *Seascope* dedicated a full page to the island venue for the project.[130] Water depths and the topography of the seafloor east of the island provided excellent resources, with a flat, sandy bottom at the 600-foot level and close access to depths of 825 and 1,025 feet desired for “bounce” dives to test equipment and human physiology. The article reported two of the five aquanauts assigned to SEALAB III had already made simulated dives in a pressure chamber at the Navy Experimental Diving Unit in Washington, D.C., remaining at 825 feet for twenty-four hours, and making a bounce dive to 1,025 feet for thirteen minutes.

Through the summer and fall of 1968, the newspaper ran articles demonstrating the significance of this project for the undersea warfare center. In July, a lengthy article featured diving supervisor Bill Bunton, who as an NEL diver had participated in SEALAB II. For his contributions to that project, he had received the Navy Superior Civilian Service Award, the Navy’s second highest. One of the transfers to the new NUWC San Diego facility, he had been selected as the diver-photographer for the fourth team of the SEALAB III crew. The article noted he had already made an eight-day simulated saturation dive to 650 feet in preparation for the project.[131]

In October, issues were dedicated to the Center’s Public Works Department preparations to support the project and to the actual habitat arrival at the Long Beach facility.[132] The massive 300-ton, 58-foot-long cylindrical structure was fitted

---

[129] “Fact Sheet On Sealab [sic],” Naval Ocean Systems Center, San Diego, California, undated.
[130] Naval Undersea Warfare Center *Seascope*, March 22, 1968, 3.
[131] NUWC *Seascope*, July 5, 1968, 1.
[132] NUWC *Seascope*, October 11 and 18, 1968,1.

with a conning tower, causing the appearance of a stubby submarine but with scores of exterior connection points for electrical cables and hoses. One article observed, “Inside, it resembles the interior of a submarine and contains a maze of dials, valves, switches, electronic equipment, a compact galley, a bio-medical and marine research laboratory, and berthing facilities for nine Aquanauts.”

The next issue, the paper’s first eight-pager, celebrated the Navy’s birthday—the 193rd anniversary of the service’s establishment on October 13, 1775—and included a two-page spread detailing in words and numerous photos the efforts of the NUWC Supply Department to “Satisfy Sealab III’s Appetite.” That appetite included a vast array of items from “food and medicine to office equipment… to the basic IX-501 (Elk River) vessel itself…”[133]

USS *Elk River* (IX-501)

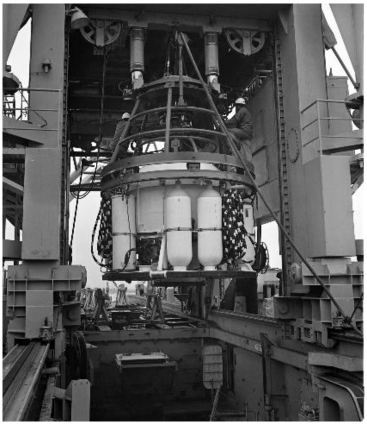
Several months earlier the newspaper had devoted a full page to the USS *Elk River* (IX-501), a unique floating asset about to join the Center’s small fleet. A late World War II landing craft (medium, rocket) originally intended to support amphibious landings, the Supply Department had pulled it out of the mothball fleet in San Diego and had it towed to New Orleans for substantial reconfiguration.

According to Ralph Myers, a range technician detailed on-scene to oversee the project since he had previous experience at the Long Beach Naval Shipyard:

> We had to convert the LSM(R) to a range operation ship… So [it] was cut in half twice, and a section in the middle was taken out. And we put sponsons on the side, with the well in the center, where we could lower down [equipment for] whatever the test was… And we put a track for the full length to the ship back from the superstructure and over the well with a crane. A crane would roll back over the rails and lower stuff down into the well.[134]

Following the major refurbishment at a commercial shipyard in New Orleans, the ship steamed to San Francisco for additional equipment installation and continued south to San Clemente Island preparatory to supporting a wide variety of projects of the Deep Submergence Systems Project (DSSP). As described in the

[133] NUWC *Seascope*, October 25, 1968, 4.
[134] Ralph Myers, Jr. NIWC Pacific oral history interview conducted by Dan Cisco and Tom LaPuzza March 3, 2020, 6.



SEALAB support ship USS *Elk River* (IX-501, top right) with close-up of a Personnel Transfer Capsule (left); SEALAB III habitat at Long Beach prior to move to San Clemente Island.

previous chapter, DSSP was a spin-off of the Polaris-developing Special Projects Office, established to carry out the technical development plan for deep ocean technology. The plan included such premier projects as the Deep Submergence Rescue Vehicle and Mark II Deep Dive System. The latter would figure critically in the tasking assigned to SEALAB III and to the landing craft, as Navy divers tested the limits of human physiology and diving hardware in the deep ocean.

Elk River was 225 feet long, with a 50-foot beam and a displacement of 1,800 tons. Essential to its support of SEALAB III and other deep-ocean projects was the 55 by 18-foot well amidships, open to the sea. Through this well, Personnel Transfer Capsules (PTC) would ferry divers to and from the SEALAB habitat. The gantry crane operating along the ship's deck moved the PTCs from their normal positions mated with deck decompression chambers to the well for the descent to the habitat.

The elaborate system of sealed pressure vessels on *Elk River* would allow saturation divers to begin compression to appropriate depth while still on the ship and while transiting to the habitat in a PTC. Their bodies would be maintained at the required depth pressure through their stay in the habitat and expeditions out to open water to perform various working tasks. At the conclusion of their specified time limits underwater, the divers would begin the lengthy (about seven days) decompression process in the PTC enroute to the surface, then transfer to an *Elk River*'s deck decompression chamber to conclude it. (The SEALAB I aquanauts remained at their 193-foot-depth for twelve days; for SEALAB II divers it had been fifteen days; for SEALAB III it was planned for twelve days per dive team.)

Disaster strikes

For the better part of a year, then, NUWC personnel in a wide variety of professions supported the approaching culmination of all those efforts in two months of underwater living by about four dozen Navy divers. Unfortunately, it was not to be. The habitat was lowered into position on February 15, 1969, and almost immediately substantial leakage of the helium-oxygen atmosphere was detected. Ralph Myers explained, "The habitat was losing pressure inside due to air leaking out through cable connectors in the side. A submarine was brought out to help with the problem. The submarine was used to pump air down to the habitat to pressurize it so that it would not flood."[135] Early in the morning of February 17, a team of four divers was sent down in a PTC to assess the situation. According to Myers, the habitat was over-pressurized, preventing the divers from opening the hatch to gain access to the interior. On the bottom at a depth of 610 feet, one of the divers, Barry Cannon, was observed in distress. His diving buddy pulled him back into the PTC, which immediately returned to the surface while the trio of divers worked furiously to save him. He was pronounced dead when the PTC reached the *Elk River*.[136]

In the meantime, the decision was made for an emergency lift of the habitat, which culminated in the early morning hours of February 18 with the structure broaching the surface.

A board of investigation convened February 28, with three naval officers representing essential aspects of the Man-in-the-Sea Program interviewing witnesses and reviewing records to determine how Barry Cannon inhaled a lethal amount of carbon dioxide that killed him. It wasn't until the end of September that the Navy issued a report on the incident, commending the dive team members who tried to save his life and issuing letters of admonition to the equipment manager and project commander. SEALAB faded into nothingness.

Mark II DDS

As mentioned above, original plans called for evaluation of the Mark II Deep Dive System as part of the SEALAB III project. The system was designed for deployment aboard the Navy's new submarine rescue ships (ASR-21 and 22), which were under construction at the time. With the abrupt termination of SEALAB, the effort on the diving system was put on hold temporarily. Recognizing the importance of the system, however, and the fact it would be integral to the operational readiness of the rescue ships, the Navy resumed testing in May 1969. The operational aspects of that testing were assigned to the Naval Undersea Research and Development Center (NURDC).[137] (The Naval Undersea Warfare Center's name had been changed April 1, based on the challenge in trying

[135] Ralph Myers interview, 7.
[136] NUWC *Seascope*, February 21, 1969, 1.
[137] NURDC *Seascope*, May 30, 1969, 1.

to recruit college-graduate scientists and engineers to a "warfare" center in the midst of substantial anti-Vietnam War sentiment.)

NURDC had designed and supervised installation of the deep dive system aboard *Elk River*, including the deck decompression chambers, PTCs, main control consoles, and handling equipment required to deploy the PTCs. With SEALAB terminated, the ship concentrated on evaluation of the dive system for several months in the summer of 1969. In October, NURDC Commander Captain Charles Bishop notified the Deep Submergence Systems Project director plans were not progressing well:

> Because of the availability of the IX-501 and the high priority of the Deep Diver [sic] Support System MK II for the Sealab [sic] program, it was agreed in recognition of the time schedule to temporarily install the DDS MKII in the IX-501 even though the space available was too small and it was known that the installation would be compromised from an operational standpoint.[138]

He advised the system was not operational and would require "considerable rework," which was beginning at the San Francisco Naval Shipyard. He cautioned, however, the proposed rework in "our technical judgment… will not be in the best interests of the overall Navy program since in our opinion the ELK RIVER [sic] cannot be configured to achieve satisfactory operational status." He suggested instead removal of the system from *Elk River*, reworking and testing it to ensure deficiencies had been corrected so it could be installed on the submarine rescue ships (ASRs). In mid-December, the commander of Naval Ship Systems Command wrote the Chief of Naval Material, citing Captain Bishop's letter and commenting several of his proposals "have considerable merit."[139] He concurred if the two systems on *Elk River* were available, serious consideration should be given to installing them on the ASRs, which in fact did occur.

TV star

The *Elk River* was assigned to the undersea center for a number of years, and as described played a significant role in the upgrade of Navy deep-diving systems.

---

[138] AIR MAIL letter from Commander, Naval Undersea Research & Development Center to Director, Deep Submergence Systems Project, PM11, Ser no. 65-100 of 31 October 1969.

[139] Commander, Naval Ship Systems Command (SHAPM 382) letter of 18 December 1969 to Chief of Naval Material, Ser. PMS 382.31/2744.

Additionally, the ship was a television star, as many of the pilot episode scenes of the TV series *The Man from Atlantis* were filmed aboard.[140] Active-duty sailors assigned to the ship served as extras, walking through scenes carrying fire hoses and other paraphernalia to lend reality to the production. Some months later, the ship also served as a backdrop for an episode of the TV series *The Bionic Woman*.

The previous chapter discussed the Technical Development Plan, which provided the roadmap for the Navy's high-level and project-level work in ocean technology. Funded and directed by the Deep Submergence Systems Project, the work involved potentially critical future requirements: rescuing the crew of a submarine stranded on the bottom (Deep Submergence Rescue Vehicle); recovery of a submarine-sized "something" (Large Object Salvage System); increasing the depth capability of Navy divers (Mark II Deep Dive System); and establishing a capability for extended habitation at continental-shelf depths (SEALAB III). The Navy labs on Point Loma and in Pasadena would play essential roles in most of those efforts in the ensuing decades of the 1970s and 1980s.

Reflections of societal changes

The decade of the 1960s, noted previously for substantial change, was also one of significant growth at the California Navy labs. By 1965, NEL had more than 1,500 civilian billets and 150 military, with a budget of more than $40 million. With a similar budget of $41 million, NOTS Pasadena had about half as many personnel—800 civilians and almost 200 naval officers and sailors.[141]

Although there was a smattering of women in technical positions, most held support and administrative jobs at NOTS Pasadena and NEL during and after World War II. The social progress of the 1960s helped change that, as more women were hired into technical jobs. In several instances, the wife worked in partnership with her husband. For example, Katherine LaFond recorded and analyzed data for Eugene LaFond's oceanographic surveys for NEL. "Gene and I were up for every station and I took all the records," she recalled. "I did all the computations from those data... That was kind of an exception for a wife to be

[140] Naval Undersea Center *Seascope*, October 22, 1976, 3.
[141] *Fifty Years*, 61 & 65.

working at the Navy."[142] (Their son Bill, a youngster at the time, would also work for the lab when he grew up.)

Seeking to recognize exemplary efforts, NELC established an Honorary Woman of the Year Award in 1969. Motion picture production specialist Olive Thompson was the first recipient, cited for "contribution toward communicating the NELC scientific story through the medium of motion pictures."[143]

In Pasadena, Ph.D. geologist Catherine Campbell headed the Publications and Photography Branch, while, as noted in the Chapter 7 personnel vignette, physicist Bea Humason analyzed torpedo performance during testing.[144] Dr. Campbell had worked at California Institute of Technology during World War II, employed on government meteorology and rocket projects. Shortly afterward, she went to work at the NOTS Pasadena Annex as a technical writer and editor, then was selected branch head in 1954. She received five outstanding ratings in the decade of the 1950s, four accompanied by Superior Accomplishment Awards, and she was cited as the top Civil Service professional woman in the greater Los Angeles area in 1960 (out of a field of 27,500 women!).[145]

NOTS China Lake, with a substantially larger workforce than its Pasadena Annex or NEL, employed scores of women in the early 1960s as mathematicians, physicists, statisticians, and chemists. Physicist Dr. Marguerite M. Rogers (who also had worked with her husband, both at China Lake and several universities) was selected to head the Air-to-Surface Weapons Division in 1962.[146] Her leadership in that role earned her the prestigious L.T.E. Thompson Award in 1965, the first female recipient, and the Navy Superior Civilian Service Award, its second highest, the following year.[147] Another physicist, Dr. Jean M. Bennett, was recognized for her research advancing precision in comparators, increasing by ten times their accuracy for comparing differential voltages. She worked in a branch headed by her husband, also a Ph.D. optics researcher.[148]

Similarly encouraging change had been evident in the mid-1950s as the first

---

142 Brian Shoemaker, "Interview with Dr. Eugene LaFond," February 27, 2000. (Katherine LaFond participated in the interview.)
143 NELC Command History, 1968, Administrative and Management Data, 10/15 (1968).
144 NOTS *Rocketeer* May 26, 1961, 3, and June 10, 1960, 3.
145 NOTS *Rocketeer*, February 5, 1960, 3 and May 26, 1961 3.
146 NOTS *Rocketeer*, November 2, 1962, 4.
147 NOTS *Rocketeer*, November 12, 1965, 3.
148 NOTS *Rocketeer*, August 13, 1965, 1.

African-American technical personnel joined the payroll. Mechanical engineer John Watkins came to Pasadena in 1954 after three years with the Department of the Interior. Beginning work on the Mark 44 torpedo, of which he was later project manager, he ultimately became a division head in the weapons department before his retirement in 1983. Don Robinson, who started on the lab's co-op work-study program in 1956 while a University of California Berkeley student, came to work full-time in 1959 in the torpedo simulation lab. He worked on the first weapons control system to use a general-purpose digital computer—the Anti-Submarine Rocket. Robinson and Watkins were joined in 1965 by Rubye Watkins (no relation, and shortly thereafter Rubye Hagan), a graduate of Tennessee State University with a master's degree in mathematics. Hagan was one of the Center's "computers," brilliant women mathematicians, many of them African-American, whose contributions to the country's technical progress were given long-overdue attention in the book (and film) *Hidden Figures*. In addition to her role as lead analyst on the Torpedo Mark 50 simulation program, Hagan served as an energetic recruiter and active participant in the NEL (and NELC and NOSC) Equal Employment Opportunity programs.[149] She retired with the transfer of the torpedo development work to the East Coast as the result of BRAC '91 (see Volume II).

Somewhat coincident with the large-scale ASW command and control system development at NEL described earlier was a more focused effort to apply control system technology to individual shipboard equipment. It was pursued by a young African-American engineer who received major laboratory recognition but whose significant claims to fame would occur after he went elsewhere.[150]

John Slaughter's first supervisor at NEL had offered him a GS-11 position, rather than the GS-12 open position for which he had applied and for which he was eligible according to the Civil Service Commission, because "I would be responsible for supervising a group of people, and he was not sure that they would be receptive to having an African-American as a supervisor."[151]

He accepted the lower position offered (at a salary also lower than he was

---

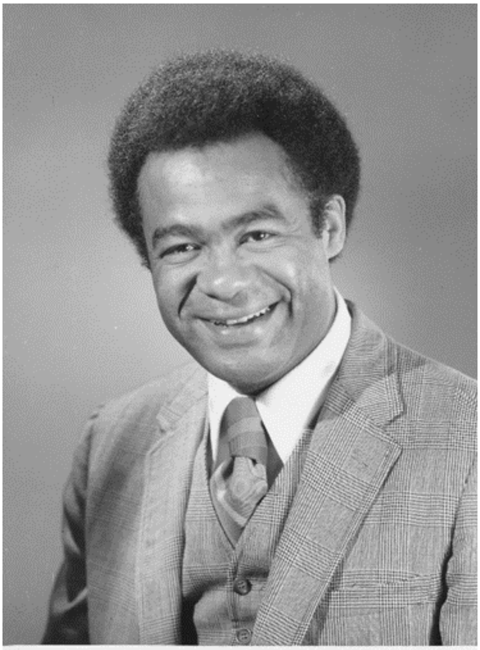
[149] Naval Ocean Systems Center *Outlook*, September 6, 1985, 2.

[150] Dr. John Slaughter's post-Navy employment is impressive, including key positions at the University of Washington, University of Maryland, and Occidental College, where he was president 1988-1999. Most significant was Assistant Director and then Director of the National Science Foundation, the latter of which he declined until President Jimmy Carter telephoned and personally requested he accept it.

[151] Dr. John Slaughter oral history interview conducted by Tom LaPuzza, January 21, 2020, 3.

already making in industry) because he was attracted to the project work at NEL. He was assigned to "look into" the potential of automatic control systems.

"I got fascinated by this idea of sample data control systems and ultimately… built a small team of people who wanted to work in this area," he said. He purchased an analog computer, connected it to the Naval Tactical Data System's USQ-20, which "ultimately led to successful demonstration, I think, for the first time, of how to use a general-purpose computer to control large systems."[152]



Dr. John Slaughter

Conceding his interest was more in helping others achieve their goals by providing needed resources "and then stand on the sidelines and cheer them on," he advanced, with helpful direction from Walt Mitchel and mentoring from Chuck Manning, to head several technical divisions. On the way he earned a Ph.D. from the University of California San Diego, a stepping stone to senior leadership:

> At one point, I said to Mr. Manning, 'You know, when you retire, I would like to have your job.' And he said, 'Well, if you want my job, you're going to have to get a Ph.D., because I'm the last

[152] Slaughter interview, 4.

person in this position who has it without a doctorate.' That's what really encouraged me, motivated me to go get a Ph.D.…Mr. Manning made arrangements for me to have a full year off at full salary to complete my degree. And to show you how things work out, I took my defense of my dissertation one morning in September of 1971, passed my exam, was congratulated for completing it, went to the laboratory, interviewed for Mr. Manning's job, got the job the same day."[153]

The position was head of the Information Technology Department. (He was the first, by almost half a century, of three African-American department heads in the history of the Point Loma Navy lab.) Interviewed shortly after the appointment, he said he was committed to establishing rapport not only with his division heads, whom he supervised directly, "but also with all the people in the line. This is particularly vital for the young professionals whose skills, enthusiasm, and inquisitiveness are our links to the future."[154]

Slaughter departed the lab in 1975 for a position at the University of Washington, heading its Applied Physics Lab, where he continued work on Navy-sponsored underwater acoustics projects. It was the beginning of decades of university positions. After eleven years as president of Occidental College in Los Angeles, he was selected the Melbo Professor of Leadership in Education of the University of Southern California.[155] After nearly a decade in New York heading the National Action Council for Minorities in Engineering, he returned to USC, where he continues teaching classes into the 2020s because

> I love interacting with students… I teach freshmen generally in the spring, and I teach graduate students in the fall… I teach a course called Technology and Society, helping young people understand that technology is much more than iPhones and iPads… I love to teach freshmen because I learn so much.[156]

Early base closures

Several decades before the formal Base Closure and Realignment Commission (BRAC) process shuttered hundreds of military bases and

[153] Slaughter interview, 13-14.
[154] NELC *Calendar*, October 22, 1971, 2.
[155] Dr. John Slaughter interview conducted by Tina Gianoulis June 14, 2005, http://biography.jrank.org/pages/2825/Slaughter-John-Brooks.html#ixzz3LQZC1SnD accessed December 9, 2015.
[156] Dr. John Slaughter interview, January 21, 2020, 30.

laboratories, three groups of employees came to the California Navy labs following disestablishment of their organizations. In September 1969, the first of 111 transferring employees began arriving at NEL from the Applied Sciences Laboratory in Brooklyn; NEL also gained more than fifty billets of personnel choosing not to transfer. The Applied Sciences Department was established to manage the employees and their projects.[157] Several months later, it was announced one of the divisions slated for transfer from the Naval Ordnance Laboratory, Corona, to the Naval Weapons Center in the West Coast Navy lab reorganization would instead transfer to NELC, bringing in twenty-eight technical personnel.[158] On the waterfront, about fifty employees from the disestablished Naval Radiological Defense Laboratory in San Francisco arrived in the fall of 1969 at the Naval Undersea R&D Center.[159]

The West Coast laboratories

Chapter 9 discussed the various plans, strategies, and non-action related to the Pasadena facility, culminating in congressional hearings. As noted in that chapter, the original stimulus for those hearings was the Navy request for funds for a new facility at NAS Los Alamitos. That request was brushed aside to a substantial degree in a larger congressional investigation into the Navy's plans (and actually decision and formal action) to reorganize its West Coast laboratories.

Dr. Robert Frosch, Assistant Secretary of the Navy for Research and Development, testified before the special subcommittee about the facility request and as well about the reorganization on July 12, 1967:

> We determined that our view of the best organization that we could establish for these laboratories with a defined assignment mission would be to assign to NOTS China Lake the mission of research, development, test, and evaluation in air-launched weapons, air to air and air to ground (which is almost all of its going mission at the time); that the primary mission of the Navy Electronics Laboratory at San Diego be command control communications and associated research (which constitutes something about 60 or more percent of its work at the time) and that it would be wise to establish a major undersea warfare laboratory; it appeared to us this could best be done by using the NOTS Pasadena annex as the core of the new laboratory;… the new

157 NELC *Calendar*, September 26, 1969 and NELC Command History, Administrative and Management Data, 2 & 4.
158 NELC Command History, 1969, Administrative and Management Data, 5.
159 NURDC *Seascope*, November 28, 1969, 2.

laboratory would be constructed administratively by adding to the NOTS Pasadena laboratory some elements of NOTS China Lake, principally those that are sited at San Clemente Island and Point Mugu, and some at China Lake,… and finally adding to it administratively the portion of the Navy Electronics Laboratory that has been engaged in undersea warfare."[160]

This reorganization had actually occurred, at least on paper, two weeks earlier, when Secretary of the Navy Notice 5450 of 27 June 1967 announced formation of the Naval Command Control Communications Laboratory Center from most of NEL; the Naval Weapons Center from most of NOTS, with addition of the Naval Ordnance Laboratory at Corona, California; and the Naval Undersea Warfare Center from the NOTS Pasadena Annex and some NEL ocean scientists.

It was certainly a time of great confusion and stress for those involved in the front lines of a reorganization they may or may not have desired. As might be expected, some combination of disbelief, uncertainty, and lack of higher-authority direction precluded immediate progress in the reorganization. NEL was perhaps somewhat bewildered by the new "Naval Command Control Communications Laboratory Center" title, until, happily, OPNAV Notice 5450 of 13 April 1968 officially changed it to the much more familiar Naval Electronics Laboratory Center (NELC). Since the plan was for the electronics lab to continue its administrative support of its former oceanographic section that was now part of the undersea warfare center, there were few changes in that area for some time.

Change, of course, was inevitable, and if not immediate, it came soon enough. Dr. Ralph Christensen, NEL technical director since 1961 and a solid proponent of research and opponent of systems engineering at the Navy lab level, announced his retirement. (The April 25, 1969 *Calendar* ran a full page of highlights on and remarks from Christensen.) The next month, Dr. E.C. Bergman, a program manager for the National Institute of Scientific Research in Santa Monica, succeeded him. A month and a day later, Captain Mabry D. Van Orden, assigned to NEL as a technical officer working on the Omega navigation system 1956-1960, succeeded Captain William R. Boehm as the NELC commander.[161]

Before Christensen departed, he and Captain Boehm had pushed for increasing the organization's management capabilities by adopting the "Managerial Grid," a system created by a business consultancy. The grid applied

---

[160] Report and Hearings of the Special Subcommittee on Proposed Undersea Warfare Laboratory, Los Alamitos, Calif. of the Committee on Armed Services, House of Representatives, Ninetieth Congress, first session: July 12, 1967, 4044.

[161] NELC *Calendar*, June 24, 1969, 1.

the ideas of behavioral scientists to management by studying and codifying the temperaments and mindsets of successful managers.

The Center newspaper reported at the outset,

> The Grid method seeks to define leadership behavior patterns that can produce organizational excellence. The objective is to help organizations increase production through heightened individual, team, and organization performance… The grid can be used to demonstrate interactions between an organization's people, its purpose (production) and its hierarchy (managers).[162]

In the paper's next issue, Captain Boehm reported to Center employees his expectations that training 130 supervisors would gain "an increased awareness of proper management processes in people at all supervisory levels. The result should be a greater degree of effectiveness here at the Laboratory."[163]

By the end of 1968, nearly four hundred personnel had taken the Grid Phase I training, and more than a hundred Phase II.[164] The effort was serious enough that a new position, "Organizational Development Coordinator," was established.

Additional strategic initiative was evident in the very next issue of the paper, which reported on a major reorganization "to provide for increased effectiveness in carrying out the Laboratory Center's new mission emphasizing Command Control and Communications."[165] Among the high-level changes was replacement of two "laboratories" (Electronics Technology and Data Systems and Evaluation) with three, whose leaders would be deputy technical directors: Research, headed by Dr. T.J. Keary (previously head of Electronics Technology); Electromagnetics Technology, headed by H.J. Wirth; and Command Control Technology, headed by the previous Data Systems and Evaluation group leader C.S. Manning.

It was/is typical of Navy R&D organizations (and it certainly has been and is of the California Navy labs) that a set of carefully orchestrated code numbers be assigned to all organizational elements, such that clear lines of authority and responsibility can be recognized at a glance. Most of the reorganization article dealt with the new numbering system. Minimal text and an organization chart named the divisions assigned to the three laboratories and the division managers.

---

[162] NELC *Calendar*, March 8, 1968, 2.
[163] NELC *Calendar*, March 15, 1968, 3.
[164] NELC Command History 1968, Administrative and Management Data, 3/10 (1968).
[165] NELC Calendar, March 22, 1968, 2.

Undersea warfare center

Change came a little more rapidly (and necessarily so) to the Naval Undersea Warfare Center, as the long-anticipated separation from China Lake became a reality. Acting (initially) NUWC Technical Director Bill McLean chose to remain *in situ* in the desert temporarily, but the Pasadena management team of Doug Wilcox, Wally Hicks, and long-time division heads Jim Jennison, Chuck Beatty, and Bud Kunz forged ahead with planning for the new organization, with the latter three ascending to become department heads. Additionally, McLean appointed two other Pasadena division heads, Don Cozen and A.J. Tickner, to manage departments. In San Diego, three Ph.D. managers—Dan Andrews, Gilbert Curl, and Curtis Haupt—would likewise assume department leadership. On the military side, Captain Grady H. Lowe had been the Pasadena Officer-in-Charge for four years, and thus should have been relieved shortly. Instead, he was assigned to command both the Naval Weapons Center at China Lake and NUWC in Pasadena simultaneously. With headquarters of those labs 175 miles apart, and the NUWC San Diego contingent an additional ninety miles to the south, Captain Lowe's military drivers must have spent an inordinate amount of time behind the wheel.

The Navy worked quickly to relieve him of some of his burden; in September 1967 Captain Melvin R. Etheridge arrived at China Lake to become NWC commander. Although McLean was still in residence and by nature couldn't have been expected to sit on his hands, Haskell G. "Hack" Wilson, his deputy for many years, became acting TD, and began to assume leadership of NWC programs.

One of those at the working level (and he almost certainly would have said "caught in the middle") of this reorganization was Bill Powell, a fairly low-level employee whom McLean would promote to his top management team as quickly as he could. In retrospect, Powell had a different take on the NUWC establishment:

> And so they gathered up the things that were in lots of different places, and threw them all into the pot, and said, 'That's the new organization.' This took the stuff at Point Mugu away from the Naval Missile Center and transferred it to the new organization. It took the stuff that NOTS had, in piece-meal bits it had, and transferred it to the new organization. And so you end up with a bunch of people at Point Mugu that used to work for two different places; now they're together. And obviously nothing for Bill Powell to do. I was not a scientist; I was not an engineer. I'm simply providing administrative support. So I looked for a way to get out of there immediately.[166]

[166] Bill Powell oral history interview conducted by Tom LaPuzza, September 13, 2012, 16.

(As will be seen in the next chapter, he headed for the islands, and paradise.)

Not to minimize what has already been realistically characterized as "a time of great confusion and stress," but the leadership of the "new" NCCCLC/NELC and NWC organizations were in effect working with long-established laboratories in the same location with mostly the same people, plus (Corona personnel who were transferred to China Lake) or minus (NEL oceanographers) the personnel who had been transferred. On the other hand, Bill McLean, Doug Wilcox, and their associates were required to create a substantially new organization (NUWC), one discussed for years but only now established in actuality. They were tasked with establishing their headquarters in a facility that has already been discussed as substantially inadequate and to integrate into their organization several hundred engineers and technicians working ninety miles to the south in San Diego, whose projects were certainly unfamiliar and to some degree unknown to them. The inclusion of Dr. Don Wilson with the transferring employees was certainly a substantial support, as he provided a familiar and seasoned manager in place who could provide the necessary leadership while the rest of the NUWC top management worked to gain traction.

While McLean's decision to leave China Lake may have shocked many of his employees, it wouldn't have been so extraordinary to those who paid attention to what he said and wrote and how he lived his life: his interest in and love of the ocean were legendary, and he was convinced the future of the world lay not on the surface of the ocean, but under it. As the author of Volume 4 of the China Lake history states: after the fleet deployment of Sidewinder,

> McLean's next love was Moray, and the many other underwater programs the NOTS ran. He was happy to run them from the desert, testing items in the O [Officers'] Club pool and in the SNORT [Supersonic Naval Ordnance Research Track] water-brake reservoir, but when higher authority said 'the ocean stuff is going to NUWC' he wanted to go with it.[167]

Another prospective organization merger

As noted earlier in the chapter, the Naval Electronics Systems Engineering Center supported NELC's training of the USS *Nimitz* crew in the use of the Message Processing and Distribution System. The organization had begun its fleet

[167] Cliff Lawson email to Tom LaPuzza, September 7, 2017, 4.

support in 1950 as the Electronics Department of the Industrial Manager of San Diego. Eight years later the organization became the Electronics Division of the Naval Repair Facility San Diego and then in 1961 the Electronics Department. When the repair facility was closed in 1966, the small group became an entity of its own as the Naval Shore Electronic Engineering Activity, moving from the naval station to the former B-24 aircraft factory buildings on Pacific Coast Highway.[168] In 1969, the title changed to Naval Electronic Systems Command, Southwest Division. (At the time Captain W.R. Boehm was the commanding officer. He had commanded the Navy Electronics Laboratory on Point Loma from the summer of 1965 until June 24, 1969, when he was relieved by Captain M.D. Van Orden, and went immediately to the NAVELEX organization.) As will be discussed subsequently, that organization would become part of the Navy lab on Point Loma in several decades.

"Bob and Joe"

The January 31, 1969 NELC *Calendar* reported on the dual retirement of Joseph C. Thompson and Robert K. Logan earlier in the week. The pair had worked together for fifteen years in the Materials Sciences Lab, which was being phased out (thus providing the obvious stimulus for retirement). Thompson, with a B.S. degree in metallurgy from the University of Minnesota, was hired in 1952 to supervise the materials lab. He was joined by Logan three years later. Together they had "worked on every major oceanographic and engineering project in which NELC was involved," including *Trieste* and TRANSDEC. (They ran strain tests on the Bailey Bridge at the latter to determine the safety factor.[169]) The men researched anti-corrosion coatings for deep-ocean applications and performed radiation studies on marine life and electronic materials.

One of their forty technical reports, titled "Oceanography Cables and

[168] Naval Command Control and Ocean Surveillance Center In-Service Engineering West Coast Division *News*, March 1996, 6.
[169] NEL *Calendar*, 10 July 1964, 2.

Testing," was considered the definitive guidebook on cables. The assistant director of Scripps Institution of Oceanography believed their work in this area had saved the Navy $1 million in a decade's time. As part of the dental research described earlier, "They have measured forces in the mouth to learn how much pressure is required to chew various foods. They have also experimented with different types of teeth and their effects on speech to determine the optimum length and formation of the teeth."[170]

In addition to the dental/denture work, they were medical research consultants to the San Diego naval hospital, developing heart-lung pump instrumentation. Thompson worked as a materials engineer at Naval Air Station North Island for seven years before transferring to NEL. After his retirement he continued his service on the research team of Mercy Hospital and consulted with dental facilities. Logan was involved in mechanical engineering tasks before he became a materials engineer. During the interview for their retirement story, Logan stated Thompson had built the Materials Lab from "a desk and a microscope." Thompson interrupted him and said, "*Bob and Joe* have developed the Materials Lab." (Emphasis added.)

[170] NELC *Calendar*, January 31, 1969, 3.

11

Expanding Westward: The Island Laboratory

"Bill McLean had said for years, if you get people to live in an environment they might work in the environment for themselves as well as for the government, meaning things as simple as, if a guy lived on a mountaintop he might learn to get up and down the mountain better. If a guy lived next to the ocean, he might learn how to swim or dive or make a boat go faster… He talked for years about having a laboratory on an island somewhere, like San Clemente. Or Hawaii," recalled Bill Powell.[1]

In an interview forty-five years later, Powell recounted how his own career had changed quickly and quite radically based on Technical Director Bill McLean's notion of creative environments. Powell, who upon completion of his management internship at the Naval Ordnance Test Station (NOTS) China Lake had been assigned to the Behavioral Sciences Group, had been sent to Point Mugu to determine the source of friction between NOTS and Naval Missile Center employees working with the Navy's first marine mammals. Both organizations had their own dolphins, but they shared facilities. The request via his supervisor was for a general management analysis, which Powell completed. McLean's response to the report was to ask him to assume leadership of the marine mammal people at Point Mugu. For several years he served there as "coordinator for all [marine mammal] studies under NOTS sponsorship."[2]

After McLean had expressed interest in an island facility, and as rumors of impending Navy laboratory reorganization resulted in confusion and anxiety among employees of those labs in early 1967, Powell decided he wanted no part of it, and said to McLean, "I would like to go to Hawaii and do research in Hawaii, and help you open the laboratory." McLean's response: "Go!" Powell didn't need a second word. He and Clark Bowers, a contractor at Point Mugu, exchanged some ideas (although Powell in his interview said *Bowers* had the ideas) and presented

[1] Bill Powell SSC Pacific oral history interview conducted by Tom LaPuzza, September 13, 2012, 16-17.
[2] NOTS *Rocketeer*, March 19, 1965, 5.

an Independent Exploratory Development (IED) proposal to study marine mammals in the wild in Hawaii. As the effort proceeded, Powell hired Bowers as a temporary civil service employee. When they moved to Hawaii, Bowers became a permanent federal employee and provided substantial service to the Marine Mammal Program, discussed later in the chapter.

The proposal was based to a degree on Powell's training as a behaviorist, wondering if a different approach to acquiring marine mammals might affect the outcome. His expressed thought:

> Let's go catch some dolphins, but not catch them. Let's go entice them out of the wild; let's go live where they are, and see if we can get them to pay attention to us and see if we can feed them and gain behavioral control over them using the techniques that we use on trained dolphins, and if we could do that we might find a difference between an animal [collected from the wild]… [and] one that had volunteered.[3]

Appropriate site located

Don Moore, an engineer whose China Lake organization was almost always the first to accept the challenge to work one of Bill McLean's "out on the edge" ideas, was a firm believer in empirical evidence. According to Powell, he suggested a fact-finding tour to establish in a credible fashion the value to the Navy of a laboratory in Hawaii. Since a principal attraction of the plan was the study of marine mammals, Forrest Wood of the Naval Missile Center (NMC) Point Mugu facility took the third place on the team, and Moore, Powell, and Wood "went on extensive travel to Hawaii looking for a place to keep dolphins."[4] They located two reasonable sites, recommending the Marine Corps Air Station at Kaneohe Bay, on the windward side of Oahu, as the best choice. Although McLean's philosophy of a creative environment highlighted remoteness from the "norm" of civilization (e.g., the sparsely inhabited high desert China Lake, which he did not choose but valued highly), his facility finders convinced him more remote locations in the islands, while certainly available, would require huge overhead costs to support. He chose Kaneohe Bay.

Powell and Bowers were joined almost immediately by mechanical engineer

---

[3] Bill Powell interview, 17.
[4] Powell interview, 18.

Dan Hightower, whose self-recommendation was that he could provide engineering support. Like Powell and Bowers, he proposed an IED project, which was also approved, and the three prepared to relocate to Hawaii.

The "creative environment"

Bill McLean said in an interview with *Life* magazine about this time that he hadn't "the foggiest notion" how innovative ideas originated.[5] He did, however, have some thoughts about what might be termed "environmental factors" contributing to innovation: for one, "isolation," not in the sense of individual solitude, but a general notion of a closed environment into which the intrusions of the outside world were minimal. China Lake, surrounded by thousands of square miles of uninhabited (and government restricted-access) desert, provided a good start to such a physical environment. Several years later, addressing the National Engineers' Week career day conference on critical environmental problems, McLean advocated "closed communities" on the moon, or "an easier and less expensive site for a closed experiment might be accomplished by building caves carved in the rock of the bottom of the sea."[6] Critical to the efficacy of it (an obvious requirement in the moon or undersea communities, but China Lake demonstrated some basic characteristics) was a close working/living/playing relationship with one's coworkers, such that the "workplace" was not merely the office or shop or test range from eight in the morning till five in the evening. Rather it extended well beyond that, following one to a cocktail party or a dinner or shared attendance at a concert or a weekend picnic, at or after which conversation continued, almost inevitably along the lines of work projects. A scientist's vague thought would be solidified by a second scientist and worked into experimental hardware by an engineer. Collaboration was critical the creative process.

So too was selflessness a positive factor, as demonstrated substantially by the NOTS China Lake ASROC collaborators. After a group of them led by department head Barney Smith had convinced a sponsor the station should lead development of the Anti-Submarine Rocket, the sponsor assigned the project to NOTS Pasadena. Despite obvious disappointment, China Lake personnel

---

[5] John Riley, "The Navy's Top Handyman," *Life* magazine, January 6, 1967, 31.

[6] "Dr. McLean proposes experiment for solving environmental problems," Naval Undersea Research and Development Center *Seascope*, May 1, 1970, 1.

contributed essentially to ASROC development, based on the general notion it didn't matter who got the credit as long as the project was successful.

The stimulus to establish a lab on a Hawaiian island was influenced by other factors than its geography, the most obvious of which was the water—warm, clear, and deep. The NOTS and NMC personnel at Point Mugu working in the water with marine mammals generally wore wet suits, based on water (influenced by air) temperatures in the holding pools and the nearby lagoon. Trainers were able to work in the water for limited periods and then had to get out to warm up. Warm Hawaiian waters would allow virtually unlimited time working with the animals.

Somewhat related, but perhaps not considered at the time, since Powell's interest was marine mammals, was water clarity. McLean had had several groups of engineers working on various manned underwater vehicles. While the Cable-controlled Underwater Recovery Vehicle had already proven the value of unmanned systems in recovering an H-bomb from the Mediterranean Sea in 1966, the NOTS technical director had a lively interest in putting people underwater. A lover of the sea and an avid water-sport enthusiast (skiing, constructing his own SCUBA gear), he envisioned low-cost underwater pleasure craft in the same mode as private aircraft and sailboats. And critical to the experience in his mind was visibility, allowing the citizen-submariners to experience the underwater environment through something more than even a picture window, according to long-time Hawaii Lab engineer Dan Hightower: "He wanted to give those people the maximum visibility and the maximum feeling that they were comfortable in the environment, and that's why he was the guy that was the first person ever to push a fully transparent-hull submersible."[7]

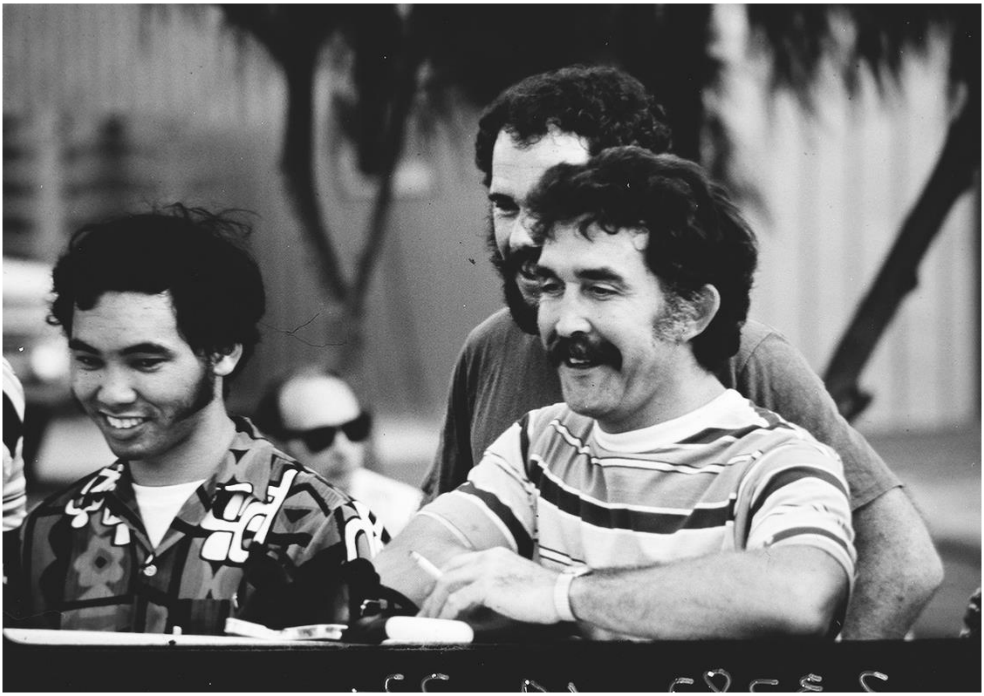
Glass and acrylic plastic transparent domes worked substantially more effectively in clear Hawaiian waters.

Again, benefitting an effort Hightower himself would pursue shortly, Hawaii provided abyssal-depth waters in the deep troughs between islands, where Navy deep-ocean technology could be tested fairly close to the lab. Hawaii also offered literally thousands of venues with immediate access to ocean waters, something that was impossible at China Lake.

A variation on the isolation theme, voiced by several of the station's Hawaii pioneers, was the distance to Washington, D.C. The fairly remote desert at China

[7] Dan Hightower phone interview with Tom LaPuzza, December 21, 2011.

Lake did preclude (or at least discourage) frequent check-up visits, but a sponsor or his representative could take a flight out, spend the better part of a day, and get a flight back, thus missing only two days in the office. That wasn't possible if the destination was Hawaii.



Celebrating christening of the Remote Unmanned Work System were (l-r) Mike Shimamoto, Doug Murphy, and Dan Hightower, the very first Hawaii Lab employee.

With those various advantages in mind, Bill McLean issued his "Go!" response to Bill Powell, and the latter complied. In late 1967 (by which time they were employees of the new Naval Undersea Warfare Center), Powell, Clark Bowers, and Dan Hightower flew to Hawaii, traveled across the island of Oahu to the windward side, and appeared at the Marine Corps Air Station Kaneohe Bay. They discovered a generally deserted hangar with some abandoned phone wires and derelict telephones. Matching a couple of them, they were able to call their technical director, Bill McLean, and report, "The Hawaii Lab has been established with its first three employees." (Hightower later claimed precedence: "As a matter of fact, based on the dates on the PCS [Permanent Change of Station] orders, I was the first official Hawaii Lab employee, beginning in November 1967."[8])

Establishment effort begins

Obviously, it took more than a long-distance call on a pirated phone to establish an actual facility, but it was a start. Over the next several months, the trio labored to strengthen an initially questionable relationship with the Marines whose base they had invaded. The base commander told Bill Powell he'd like to help, but didn't know what he could do, and then went about his business. Based on his experiences during his management analysis project at Point Mugu, Powell had some ideas, but lacking any status (and especially any title) little progress was made. He did a couple of things to remedy that. First, he advised his technical director the Marines were disinclined to assist him when his only accurate response to the question "Who are you?" was "I'm Bill." He suggested a title of some kind might solve the problem. Shortly thereafter, he and McLean were staying in a Pasadena hotel attending a management meeting of the new Naval Undersea Warfare Center, and he noticed a sign on a door reading "Resident Manager." He proposed that as his title. McLean, recognizing he had no authority for a commanding officer or even an officer-in-charge for his fledgling laboratory, and none for a civilian director, readily accepted the title and conferred it on Powell.[9]

Although that solved the title issue, Marine assistance and support continued to be slow in materializing. Powell contacted Dr. Sam Rothman, who was responsible for the Independent Exploratory Development program at the Naval Material Command (and who later would be one of his major sponsors) and asked if he could assist. Rothman did so, directly requesting the Commandant of the Marine Corps to provide the support. The latter sent a message via the chain-of-command to the base commander, authorizing him to provide any support the "Navy lab resident manager" needed, and help was immediately forthcoming.

---

[8] "Three acting department heads named," Naval Ocean Systems Center (NOSC) *Outlook*, February 6, 1987, 3.

[9] Bill Powell interview, 30.

The assistance requested and provided was fairly mundane: security badges so the handful of NUWC personnel could get on the base, a location where official mail could be sent and received, a means of sending secret telegrams. With those basic administrative matters handled, efforts proceeded to establish office spaces, connect working phone lines, and recruit more technical personnel from China Lake and from the local community.

The latter included a secretary who had been working for the Army Corps of Engineers in Honolulu for five years, Betty Imai. For the selected applicant filling the first clerical position at the Hawaii Lab, it was something of a homecoming: her previous federal service included a job as secretary to the commanding officer of the Pacific Missile Range activity, which once stood on the Marine Corps Air Station property now occupied by the NUWC Hawaii Lab.

In an interview two decades later, she said,

> When we started the lab, we had to set up laboratory policies and procedures and do a lot of liaison with the air station. We were fortunate to have a lot of cooperation from the people here on the base. The main challenge then was to learn my job, systemize it to become as efficient as possible,[10]

Imai worked for Powell initially, but when a director for the Hawaii facility was selected, she served the rest of her lengthy tour as the director's secretary. When a naval officer was detailed as the acting director, she provided such substantial support he awarded her a quality salary increase. She retired in 1988 after twenty years at the Hawaii Lab and a total twenty-eight years federal service.

"Proposal approved"

Based on their IED proposal, Powell and Bowers had moved to Hawaii to set up a "volunteer" dolphin training program. According to Powell, their fairly fundamental proposal sought enough funding to set up office space and animal holding areas and begin operations: "We were proposing to study dolphins—swimming, communication, all kinds of general stuff."[11]

In March of 1968, several months after he had arrived in Hawaii and set up a

[10] NOSC *Outlook*, September 20, 1985, 2.
[11] Bill Powell interview, 23.

shoe-string operation in a borrowed hangar, Powell received a phone call from Washington, D.C., advising his IED proposal had been approved and funded for more than a million dollars. Although the proposal had been the basis of the transfer to Hawaii, he'd forgotten exactly what it was, other than acquiring and training dolphins: "We had to go back and find out what we were proposing to do," which turned out to be "all kinds of general stuff."

The funding they were provided, however, had no such interest. It was for "a single issue… use the dolphins to detect swimmers trying to blow up American materials and things."

Powell responded he had never made a proposal for anything like that, but was told to proceed nevertheless toward that objective. Although he had been cited as "coordinator" of NOTS marine mammal efforts, "I had no responsibilities to be in charge of anything at Point Mugu." He contacted McLean, who at the time was substantially involved in establishment of the new Naval Undersea Warfare Center, advised about the million-dollar funding and six-month deadline, and asked what he was going to do. McLean's response, "You're in charge," was not what he wanted to hear, but after the direction was repeated, "I accepted the responsibility and grabbed everybody I could find that could do anything… And [we] collectively as a team built the Navy's first swimmer defense system."[12]

The project, he learned, had originated with one of the many serendipitous relationships engendered by and at China Lake: a good friend of Bill McLean's happened to be the father of Admiral Elmo R. Zumwalt, Jr., at the time Commander, Naval Forces Vietnam (and later Chief of Naval Operations). Zumwalt Junior had said the most serious threat in Vietnam was swimmer-sappers blowing up ammunition storage facilities and similar critically important targets close to the water. A completely unrelated McLean-Zumwalt Senior discussion about the former's marine mammals inexplicably had matched enemy attacks from the water with those mammals in some vague and ill-defined relationship.

With funding and tasking in place and the clock ticking, McLean dispatched Powell to Vietnam to determine how the handful of Naval Undersea Warfare Center personnel in Hawaii (backed up, of course, by the collective resources of the entire NUWC) could address Admiral Zumwalt's key issue. After discussion of alternatives, the decision was made to train dolphins for the task.

---

[12] Bill Powell interview, 25.

Powell reached back to the mainland for reinforcements—administrative assistance, purchasing agents, "stuff." The latter included a steady supply of fish to feed the dolphins and freezers to store it. The fish were courtesy of Marty Conboy, the Navy diver who had joined Sam Ridgway in the early days of the mammal program, completed his enlistment, and taken a job as a civilian working with the animals. In time, Conboy would manage an operational sea lion recovery system. For the moment, he was tasked with securing high-quality fish for the marine mammals at Point Mugu and those scheduled for transport to Hawaii. (The separate programs to study and find uses for marine mammals at the Naval Ordnance Test Station and Naval Missile Center at Point Mugu were consolidated with the establishment of NUWC, under its direction, in December 1967.[13])

Initially two dolphins were flown to Hawaii to begin training for the requested capability. Powell was fortunate that some preliminary training had already begun. Following the SEALAB II experience with Tuffy and the question posed by the project medical officer, Captain George Bond, whether a dolphin could detect a diver, Sam Ridgway and his associates had done some initial work along those lines:

> To test his detection ability, we had swimmers go into the area. When he detected a swimmer, he left his buoy route and came back to home base and signaled us. And we also then trained him—and this was all during a period of maybe two months' time because of this intensive experience at SEALAB—to detect divers. He could detect SCUBA divers a long, long distance away. And we found out that he could detect swimmers… When we reported those results up the chain, people did get excited about it. Captain George Bond probably had mentioned it in Washington… we believe that the early work we did at Point Mugu, mainly with Tuffy, but also with another dolphin, helped push that forward and gave them data that they could point to when they established the Hawaii Laboratory and the Short Time program.[14]

With sponsor direction to establish a swimmer-defense capability (and "capability" was a critical word; Powell emphasized no requirement had been given for an operational system to deploy anywhere) and tasking acceptance by NUWC Hawaii personnel, an immediate requirement surfaced for holding facilities for the animals. Powell hired Bill Steele to build appropriate enclosures. He had some valuable experience, Powell reported: "It turns out that while in the Navy he built the facilities in Key West that were used by the CIA," which sponsored an earlier program studying potential uses of marine mammals for

[13] Naval Undersea Warfare Center Command History, 1968, iv.
[14] Dr. Sam Ridgway SSC Pacific oral history interview II, conducted by Tom LaPuzza, August 8, 2012, 4-6.

operational missions. When the order came to prepare the swimmer defense "system" for deployment, some of those former CIA animals would be employed for that purpose.[15]

Design and fabrication of hardware, development of procedures, and training of dolphins and personnel—military and civilian—proceeded.

Hawaii Lab "Grand Opening"

This project, substantially classified, was kept under wraps. The importance of the new lab, however, and its promising potential to advance the mission of the Naval Undersea Warfare Center, required reasonable publicity, both publicly and in-house. NUWC's newspaper ran a five-column front-page headline in fall 1968: "Hawaii lab announced, opened."[16] The article featured photos of McLean shaking hands with the Marine air station commanding officer and of an enclosure with a "porpoise, performing for visitors."

At a luncheon meeting of the Marine Technology Society held in conjunction with the laboratory's "grand opening," McLean announced the intention to partner with related organizations (such as the University of Hawaii and a commercial enterprise called Sea Life Park) "to make Hawaii the oceanographic center of the Pacific." He noted the benefits of a Navy research facility in Hawaii for fleet support, sonar, and ocean studies: "We expect to have an increasing responsibility in ensuring that new developments will be able to bridge the gaps between development, production and fleet use. Hawaii and San Diego are obvious locations for fleet support activities."[17]

He emphasized the study of sonar propagation was an important NUWC responsibility, and sonar conditions in the Pacific differed significantly from those in the Atlantic. Hawaii's position in mid-Pacific heightened its importance in the Center's sonar studies.

During the meeting, McLean introduced the Hawaii Lab director, Jesse B.

[15] Bill Powell interview, 33. As clarified below, "system" had a precise definition.
[16] NUWC *Seascope*, September 27, 1968, 1.
[17] NUWC *Seascope*, September 27, 1968, 1-2.

Seeking appropriate attention for its new Hawaii laboratory, NUWC held a grand opening September 20, 1968. One of the Atlantic bottlenose dolphins transferred from Point Mugu performed for admiring attendees, including Don Moore, head of the Undersea Engineering Division (left, back to camera); *Seascope* editor Virginia Libby and NUWC Public Affairs Officer Carney Kraemer; and Hop Porter, heading two engineering branches at the time but ultimately the second manager of the Marine Mammal Program (far right).

Burks, who was a retired Navy captain. Burks had something of a second-cousin relationship with the new organization: a naval aviator for thirty years, he had previously been the commanding officer of the naval air facility at the Naval Ordnance Test Station at China Lake from 1949 until 1951. He had completed his Navy career in 1964 and was particularly suited to the lab directorship by virtue of his master's degree in oceanography from the University of Hawaii. Additionally, his service as a naval aviator made him a more than welcome tenant on a Marine Corps air station, according to Dan Hightower.[18]

Also introduced in the Center paper were the two main technical project

[18] Telephone conversation, Dan Hightower with Tom LaPuzza, January 16, 2019.

leaders: Bill Powell, who headed the Bio-Sciences Division; and Don Moore, head of the Undersea Engineering Division, "a prime worker on advanced submersibles." As noted earlier, when Bill Powell approached McLean about transferring to Hawaii to set up the lab, Moore had pushed for the fact-finding trip to establish credibility. Moore told an interviewer several decades later that when the undersea warfare center was formed, he'd decided to follow McLean's interest in an island laboratory. He asked the engineers in his division of eighty to ninety people at China Lake if any of them was interested in moving to Hawaii. He said he got about half a dozen volunteers to relocate with him.[19] Moore ran the Hawaii division from China Lake for several months, before transferring himself in 1968.

Among the volunteers responding to Moore's offer was Doug Murphy, a Fresno State College mechanical engineering alumnus who had arrived at China Lake as a Junior Professional in 1965. Murphy had worked for several years for Moore on the development of underwater vehicles. When he arrived at the Hawaii Lab in 1968, he was assigned leadership of the Submersible Systems Branch.[20]

Another arrival several months before the lab's formal opening was Homer O. "Hop" Porter, an earlier Fresno State graduate who over succeeding decades would play a major role in leading the Hawaii Lab (as well as the laboratory on Point Loma). A mechanical engineer from the San Joaquin Valley, an equally hot but much more fruitful section of California than China Lake, Porter had come to NOTS in 1961 and subsequently advanced to branch head. After several years in that position, he mentioned to his division head the daily tasking was becoming monotonous. Several days later, the supervisor received a call, requesting Porter's services for a fifteen-month assignment in Hawaii. If the earlier conversation had not occurred, Porter said, the request would have been turned down.

Instead, Porter was in Hawaii shortly thereafter, working at Camp Smith for a fleet command analysis group on an assignment for the Vietnam Laboratory Assistance Program (VLAP). Porter knew Don Moore fairly well from social events at China Lake, and, more importantly, was the one who had convinced fellow Fresno State graduate Dan Hightower to work at China Lake in the first place. During his VLAP off-duty hours, Porter got together with them and other former NOTS employees at social events. As was the China Lake tradition, social

[19] Don Moore Naval Weapons Center interview by Elizabeth Babcock, October 11, 1990, 42.

[20] "Doug Murphy retires with 34 years of service," Space and Naval Warfare Systems Center San Diego *Outlook*, October 15, 1999, 3.

gatherings were equally, if not substantially, occasions for technical discussions, one of the advantages Bill McLean championed of recreating with coworkers. During one of those, Moore offered Porter a branch head position. Porter, whose positive response was instantaneous, nevertheless suggested an alternative based on his interests: "I knew he was going to start an analysis group also and I insisted that I wanted the analysis group and he said, 'Okay, I'll give you both.'" (Porter acknowledged his two branches combined initially included only half a dozen people.) Porter returned to China Lake at the end of his VLAP assignment merely to resign his position there and collect his belongings for the move to Hawaii.

The NUC Hawaii Laboratory in 1971

San Diego reorganizations affect Hawaii

While small numbers of personnel were arriving and an organization structure was forming at Kaneohe Bay to support initially limited marine mammal and ocean engineering efforts, Bill McLean had moved to San Diego and was forming a substantially larger and more detailed organizational structure for the entirety of the fledgling Naval Undersea Warfare Center. A Navy directive (Office of Chief of Naval Operations Note 5450, dated 26 June 1968) had mandated relocation of Center headquarters from Pasadena to San Diego, with the official date 1 July, a year to the day after the organization's establishment.

By the time McLean had moved physically to San Diego, he had promoted Pasadena department head Doug Wilcox to a deputy TD position similar to Don Wilson's in San Diego, and selected five Pasadena division heads and three NEL department heads to manage the eight NUWC technical departments. Although he had told Bill Powell he would have to deal with direction to establish a swimmer defense capability on his own, McLean did establish a new Research and Engineering Department (appointing himself acting department head) to support him. It consisted of Powell as the "resident manager," with absentee managers Don Moore, still at China Lake, heading the Undersea Engineering Division, and former Naval Missile Center employee Forrest G. Wood leading the Marine Bio-Science Division at Point Mugu.

McLean continued to refine his organization, making changes at the department level that trickled down through divisions and branches. By the fall of 1969, the technical director had transformed Howard Talkington's Ocean Systems Division into the Ocean Engineering Department. One of its major organizational elements was the Hawaii Division, headed by George Wilkins and including branches managed by Hop Porter and Dan Hightower. Don Moore, who over the next several years would handle significant but short-term assignments in Washington, D.C., was listed on the department staff.

Bill Powell's Bio-Systems Project Office had been relocated to the San Diego-based Ocean Sciences Department, now headed by George Anderson after the sudden death of Dr. Gilbert Curl in April 1969. Forrest Wood's division, still at Point Mugu, also had been moved into Anderson's department.

Seascope reported the staff had grown to more than forty, from whose efforts

> project work is progressing in underwater sound and visibility, study and training of marine mammals, development of spherical hulled deep submersibles, submersible diver-aid systems, development of surface support craft for work with marine mammals and studies of the sea water itself as a life support system.[21]

What the newspaper didn't mention, and what would be classified secret for

---

[21] John R. McCabe, "NUC Hawaiians use unique location to advance conquest of ocean volume," NURDC *Seascope*, July 25, 1969, 1.

decades, was the effort, headed by Powell, to develop a swimmer defense "capability" employing bottlenose dolphins.[22] His bare-bones proposal to "study dolphins" in Hawaii necessarily would have entailed months of research on resident dolphin populations, the environments they frequented, and their behavior, in order to develop a workable approach to "entice them out of the wild… and gain behavioral control over them." It had never been done with marine mammals; it certainly was not something that could be done on a schedule, and, even more impossibly, it could not be done in the handful of months provided by the sponsor seeking animals trained in operational capabilities.

Powell's "reach back" to the mainland for more staff and Marty Conboy's fish supply included a request for a couple of the dolphins Sam Ridgway and his associates had trained basically to identify swimmers and divers underwater. Within the allotted time frame, he was able to satisfy the sponsor's requirements:

> … we proceeded to develop the capability to do the job. We built a prototype system. It had equipment; it had dolphins doing different things, and we put all the pieces together and tested it by putting it in an airplane, and flying it to Key West, Florida, operating immediately after arrival, within a day after arrival, detecting swimmers in the bay. We showed that you can move dolphins; you can move the facilities; you have the trained people; you can do the thing and it works. And we flew all the stuff back to Hawaii and said, 'There, we did it. Whew.' We had no further instructions to do anything, other than this general program we started with,…[23]

First marine mammal operational system

With the tasking successfully completed, Powell and his team investigated other potential uses of the dolphins, training different behaviors, for a brief time. Then came another telephone call from Washington, with the order to prepare to deploy "the system" to Vietnam.

The term "system" in Navy parlance has substantial specificity, including a history of fairly rigorous and objective testing to ensure it performs as intended. The technical evaluation (TECHEVAL) had been completed successfully in Key

[22] Although the very first animals in the Point Mugu inventory were Pacific white-sided dolphins, the Center's principal study and use in operational systems was with Atlantic bottlenose dolphins (*Tursiops truncatus truncatus*), with a lesser interest in their Pacific cousins (*Tursiops truncatus gilli*).
[23] Bill Powell interview, 34-35.

West. Although several naval officers had participated in that, the next step, operational evaluation, required successful performance of a system capability operated entirely by military personnel. As a result, two young Navy lieutenants, trained explosive ordnance disposal (EOD) divers, were selected to train with the animals. Hal Goforth, who had participated in the Key West activity, and Les Bivens, a fellow Navy diver and friend he recruited, were ordered to the Hawaii Lab as leaders of the military group that would operate the animals in a planned real-world deployment:

> … it was determined that there was a real need in Vietnam for a swimmer defense program and it was ordered by the Navy Chief of Naval Operations that the program would be brought up to speed and deployed to Vietnam. That required additional personnel, Navy personnel. I was one of the ones that was recruited by that. Actually, Hal Goforth called me and asked me if I would be interested and I volunteered for it. Shortly after that, I was in Hawaii, learning along with a group of about twelve other sailors how to operate a marine mammal system, train them, take care of them, with technical support from some of the old-time oceanarium trainers that had been hired by the Navy to train dolphins for them.[24]

Bivens, who would in fact remain with the Marine Mammal Program for his entire lengthy Navy civilian career, was substantially impressed by the civilians with whom he worked at the Hawaii Lab:

> And the people at the lab that were teaching us were unbelievably good at doing that… It was an *excellent* working relationship, lots of respect for each other, both sides. The civilians that were helping us really respected the military and what we were going to do, and really wanted to help us succeed in that mission. And we—the military side of it—were really impressed with the expert capability of the people that were there.[25]

While the praise was perhaps well-founded, there was a challenge. Bill Powell, after receiving the second phone call, had contacted various associates to determine the projected time to prepare all the equipment required for what amounted to an operational deployment. He heard "ninety days," which related to specific hardware but not to all the equipment required, and reported that to the sponsor. Only later did he understand three months was only for a portion of the hardware, and "I had committed the whole group to delivering an operational system in ninety days." From that miscommunication and resulting sponsor expectation came the project code name: "Short Time."[26] Miscommunication

[24] Les Bivens SSC Pacific oral history interview conducted by Tom LaPuzza, February 20, 2018, 3.
[25] Les Bivens interview, 4.
[26] Bill Powell interview, 35.

notwithstanding, the group met the deadline. "It was incredible," Powell marveled.

In late 1970, Lieutenant Bivens, with Navy enlisted personnel and several Hawaii Lab civilians, traveled to Vietnam with animals fully trained and all necessary equipment. Although Lieutenant Goforth had been scheduled to deploy first, the imminent birth of his first child prompted Bivens to offer to take it. He thus would lead the first-ever deployment of a Navy marine mammal system. It was in actuality not a "system" until that deployment, for which appropriate evaluation procedures were established to certify it. Bivens commented:

> So the decision was made that since it was not a certified system, since it had not been through the OPEVAL [Operational Evaluation] yet, that the OPEVAL would actually be in Vietnam and that's why it was deployed there… to get a system in the fleet, for that purpose, as quickly as possible.

In operation, it was on station nightly for a year and a half, three dolphins working at a time in the initial configuration, the animals positioned in three stationary enclosures around "the highest-level-of-attack-probability asset," which was the ammunition pier in Cam Ranh Bay. (According to Goforth, the earlier Bill Powell reconnaissance mission to Vietnam had settled on three possible sites for operating the animals; from those the selection was made of "… Cam Ranh Bay, headquarters of Market Time and the tri-service ammunition pier that averaged forty ships per month that off-loaded tons of ordnance, millions of gallons of petroleum oil/lubricants."[27])

The basic operational principle was that each dolphin continuously scanned the waters between its enclosure and the "asset" using its highly accurate biological sonar, and if a swimmer or diver appeared in those waters, it notified its handlers. Security forces were alerted and rushed to the area to apprehend the intruder.

Lieutenant Goforth arrived six months later to take over, staying about five months. Bivens returned for another tour, before moving the system back to Hawaii. He was assigned as officer-in-charge of a new group of Navy personnel and a new set of swimmer defense dolphins, all of which moved to Guam to provide a sentry function there. With his pending discharge from naval service after months in Guam, Bivens accepted a position offer from Bill Powell, serving as his administrative officer and liaison between the military operators of the system and the Hawaii Lab's animal training and care staff.

With the conclusion of the Vietnam deployment, the Navy certified "Short

[27] Hal Goforth oral history interview conducted by Tom LaPuzza, January 23, 2018, 20.

Time" as the Mark 6 Marine Mammal System (MMS). (Incidentally, during the eighteen-month deployment there were no attacks against the ammunition pier, which had previously been the object of a number of swimmer-sapper attacks.)

As will be discussed in Volume II, the Mark 6 MMS would be deployed on several occasions during the next half century to provide a valuable defense for waterside targets against potential attacks by swimmers and divers. In every deployment, for an exercise or to an active combat zone, from that day until this (2020), civilian personnel from the Point Loma lab have accompanied military units to ensure effective operation of animals and people and highest quality care for the animals.

Powell cited

The importance of the swimmer defense capability was demonstrated a few years later, when the Commander, U.S. Third Fleet, presented the Navy's highest civilian honor, the Distinguished Civilian Service Award, to Bill Powell in 1973 for his leadership in development and initial fielding of the system.[28]

As for the lieutenants who deployed to a combat area with the system before it was a system, Les Bivens was hired as Powell's administrative assistant when he hung up his uniform. He instituted a major change in system operation, redirecting it from animals essentially stationary to an animal swimming freely with a sentry boat. He would eventually manage the Marine Mammal Program during a particularly challenging period, which will be discussed in Volume II. Goforth also left active duty but remained a naval reservist for decades. He continued working at the undersea center for some years and earned a doctorate in kinesiology, with his thesis based on dolphin research. Memories of his active-duty assignment with the Navy lab dolphins resulted eventually in a book about his experiences.[29]

[28] Naval Undersea Center *Seascope,* August 3, 1973, 1.
[29] Capt. (Ret.) Harold W. Goforth, Jr., *Defender Dolphins* (Jacksonville, Florida: Adducent, Inc., 2012).

Sea lion recovery system

Marty Conboy has been mentioned several times, based on early work with Sam Ridgway at Point Mugu and later service setting up a reliable source of quality fish for the Navy's mammals. More importantly, he left the service and moved to the undersea center's Hawaii Lab to work with sea lions.

As discussed in an earlier chapter, one of the early Point Mugu Navy dolphins, Tuffy, was the first Center marine mammal to demonstrate an operational recovery. On the other hand, trainers of the various animals with which the Center has worked—dolphins, sea lions, seals, and whales—quickly learned sea lions were the easiest to operate. They could be maintained in cages; by their nature, they could walk on their flippers on land, requiring no human intervention to transport them short distances or to get into or out of the water; and their directional hearing and low-light-level vision provided a reliable capability for finding objects underwater.

Conboy, after completing his enlistment and entering civil service at the Hawaii Lab, was tasked with turning the sea lion recovery capability, termed Project Quick Find, into an operational system:

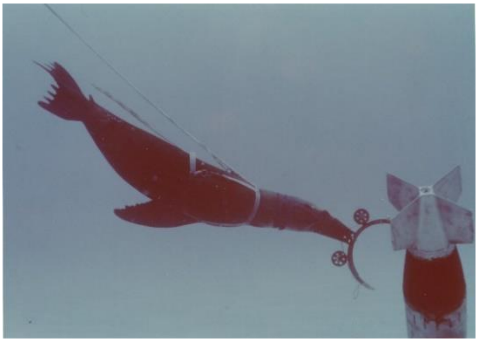
> We reasoned that a recovery system, designed around a small marine mammal that could stay out of water for long periods and move about on land, would be an easy system to transport and use. What has evolved is a remarkably uncomplicated recovery system with none of the disadvantages associated with divers and submersibles.[30]

A group of sea lions was collected from the California Channel Islands in the late 1960s and transported to Hawaii, where Conboy oversaw their training to carry a "grabber device" in their mouths underwater to a target. Pressing the device against a cylindrical object, such as a torpedo, activated a spring that turned the (letter) C-shaped device into an O shape encircling the object. A line attached to the grabber was held at the other end by one of the trainers in the rubber raft from which the sea lion was working. Once the object was hooked, the line was attached to a winch, which brought it to the surface. In November 1970, a California sea lion named Turk conclusively demonstrated system effectiveness by locating an

---

[30] Martin E. Conboy, "Deep Sea Recoveries By Sea Lions," NUC *Seascope* October 1, 1971, 3. See also: M. E. Conboy, "Project Quick Find: A Marine Mammal System for Object Recovery," NUC TP 268, Rev. 1, 1972.

Anti-Submarine Rocket (ASROC) Quality Assurance test round on the sea floor near San Nicholas Island and attaching a line for its recovery.[31]



A sea lion recovery system initially titled Quick Find became the Navy's Mark 5 Marine Mammal System, its second operational mammal system developed in Hawaii.

Quick-Find, when it had completed its own set of technical and operational evaluations, was officially designated the Mark 5 Marine Mammal System. Mark 5 has been the most cost-effective and cost-saving of the MMS operational systems, recovering hundreds of ASROC rounds for data analysis and reuse, requiring only a rubber raft, several trainers, and a shipboard crane. And a sea lion.

Whales added

While the mammal effort was based at Point Mugu but had been transferred to the Naval Undersea Warfare Center, two whales were added to the inventory.[32] The killer whales (*Orcinus orca*), and shortly thereafter a pilot whale (*Globicephala macrorhyncus*), arrived at the facility as four "porpoises" were undergoing training to support SEALAB III, planned for operation more than 600 feet underwater off San Clemente Island. As the depth of man's forays into the sea increased, the Center began enlisting deep-diving marine mammals in the effort.

The pilot whale was transported to the Hawaii Lab in December 1968, with

[31] NUC *Seascope*, October 1, 1971, 3.
[32] NUWC *Seascope*, November 29, 1968, 1.

the killer whales following in late 1969. Clark Bowers, who had arrived as a contractor with the very first contingent of Hawaii personnel, was now a Center civilian employee. He was selected to manage Project Deep Ops, a planned object recovery system closely resembling Quick-Find.[33] For the next several years, Bowers and his team developed training procedures and equipment to allow recoveries in water depths substantially in excess of 1,000 feet. The project was completed in December 1971 after successfully demonstrating its effectiveness in deep-water recoveries.

In another adaptation of the basic principle, white whales (*Delphinapterus leucas*) were trained to recover objects in the frigid waters they normally inhabit, providing a potential capability to recover objects in arctic waters.

New marine mammal capability

As will be discussed shortly, Naval Undersea Center Technical Director Dr. Bill McLean established a new department in the summer of 1973, the first one based in Hawaii. As part of the resulting reorganization, Bill Powell was selected to head it, and Hop Porter transferred from the Ocean Technology Department to work for Powell. The change would be significant for Porter, who had supported engineering requirements for the Marine Mammal Program for some time: "I remember telling Bill Powell that I could run those projects easier than I could work for the guys he had running them, and build hardware, and could do a better job. And so he offered me that opportunity."[34]

It was a substantial opportunity. Porter had begun pursuing a new potential capability for marine mammals: mine hunting. The major marine mammal capabilities developed by the undersea center and its successors over the years are swimmer defense, object recovery, and mine-hunting. Interestingly, until 1992 four of those words were classified secret, and could not be spoken in open conversation. To represent the capabilities accurately, and truthfully, the many journalists and members of the general public seeking information on animal responsibilities were told they performed "underwater surveillance for object

[33] Clark Bowers and R.S. Henderson "Project Deep Ops: Deep Object Recovery of Pilot and Killer Whales." NUC TP 306, November 1972.
[34] Hop Porter, phone conversation with Tom LaPuzza, January 16, 2019.

detection, location, marking, and recovery."[35] What they weren't told were specific objects sought—swimmers, divers, and mines. The latter represent a fairly inexpensive means of halting progress by enemy forces, both on land and in the water. The threat of mines—real, imagined, publicized whether they were in place or not—has stymied or at least slowed advance of armies and navies for decades.

The Marine Mammal Program, with Hop Porter directing the new start, began actively training bottlenose dolphins to detect, localize, and mark location of mines, with the intent Navy human divers would inspect, disarm, or explode those impeding the Navy's progress toward a desired goal. The mine-hunting capability was initiated with a requirement in the Advanced Marine Biological Systems (the program's overarching framework) Five-Year Plan of 1968, which initially addressed moored mines, but soon added mines on the sea floor, including buried mines. Mines in the water column were a reasonable target for man-made sonar systems, but mines scattered (cleverly or accidentally) among seafloor rocks and coral outcroppings represented a substantial problem, particularly in shallow water, defined generally as forty to two hundred feet deep. For one thing, a sonar beam aimed at the bottom resulted in substantial reverberation, essentially rendering almost everything indistinguishable in the clutter. Dolphins, on the other hand, boasting a biological sonar that was the envy of Center acousticians, could detect mines easily and reliably.

Eventually hardware systems were developed, some by the laboratory itself, that could detect proud (that is, standing up on the seafloor) mines with some degree of success. Buried mines, and after some period of time most proud mines become buried mines, were another story. Other Navy laboratories and private industry, beginning before the turn of the millennium, announced appropriate technologies *nearly* ready for operation. According to Dr. Mark Xitco, head of the Point Loma lab's Biosciences Division, "In 1971, they completed a demonstration that the dolphins could detect and mark 'silent' objects sitting proud on the bottom," but the system would not attain full operational capability for another decade and a half.[36] The details of this development will be related in Volume II.

An invention disclosure was filed in 1981 for the capability, titled "Underwater Object Locating and Marking Systems (U)," the "(U)" indicating the

---

[35] Space and Naval Warfare Systems Center San Diego, *Annotated Bibliography of Publications from the U.S. Navy's Marine Mammal Program*, Technical Document 627, Revision D, May 1998, vi.
[36] Dr. Mark Xitco email to Tom LaPuzza, July 6, 2020.

title was not classified but some or all of the document was. Inventors were Homer O. Porter, Bill Powell, and Ralph Penner. A query on the status of the disclosure four decades later found it would remain classified.[37]

Marine Mammal Protection Act

In October 1972, the U.S. Congress passed the Marine Mammal Protection Act (MMPA). It limited collection of marine mammals from U.S. territorial waters and collection by U.S. citizens on the high seas. The only two exceptions for collecting and maintaining marine mammals were public display and scientific research, thus presenting a clear challenge for the Center's efforts in this area. Since there was not the slightest chance of any public display, all the Navy's work with marine mammals was categorized for some years as "research," although much of that work involved development of fleet operational capabilities. As will be explained in Volume II, it would be a decade and a half before management of the Marine Mammal Program developed an approach supporting the Navy's important marine mammal capabilities consistent with the MMPA.

Peripheral benefits

In Chapter 8, the early history of the Marine Mammal Program, which began in the celebrated year of 1960, was covered in some detail. One of the individuals involved in the Point Mugu days was William E. Evans, at the time a UCLA graduate student who donated a sea lion to the Navy's marine mammal inventory. His research with the sea lion would have substantial benefits some decades later.

In the meantime, Evans completed requirements for his Ph.D. and moved to San Diego, where he focused on marine mammal research. His expertise gained him substantial news headlines in relation to another San Diego entity heavily involved in marine mammals—Sea World. As part of a scientific study, the marine park had gained authorization from the National Marine Fisheries Service (NMFS)

[37] March 28, 2018 email to Tom LaPuzza from Anthony King of the Space and Naval Warfare Systems Center Pacific Office of Counsel/Intellectual Property.

to capture and hold in its facilities a baby gray whale. Terms of the NMFS agreement included return to the wild of the whale after a year of study.

During that year, the whale, named Gigi, was maintained in good health by park veterinarians and cetologists. With appropriate care and feeding, she had grown so large her care givers had no means to return her safely to the wild. Enter Bill Evans, who developed a scenario for that return, involving the Naval Undersea Center (NUC), Navy Public Works Center, San Diego Police Department, tractor trailer trucks, barges, etc. In March 1972, that scenario unfolded, with cranes lifting the huge mammal onto foam mats on a flatbed trailer, a caravan of trucks and police cars creeping through traffic to the NUC pier, load-out onto a barge, and a short voyage to sea where the barge crane deposited the yearling whale in the customary path of gray whales migrating north from Scammon's Lagoon.[38]

An interesting coincidence is the other major front-page story in the *Seascope* issue detailing Gigi's return to the sea reported on a meeting of marine mammal trainers held at the Naval Undersea Center February 29. Dr. Ross Pepper, a psychologist at the Hawaii Lab, hosted that meeting in a NUC conference room, with the express intent of promoting professionalism among marine mammal trainers. Dr. Sam Ridgway had already initiated the International Association for Aquatic Animal Medicine (IAAAM) in 1969, and Bill Powell was seeking to develop a similar organization for trainers. The meeting in 1972 would eventually spawn the International Marine Animal Trainers Association (IMATA).[39]

George Wilkins

Like Bill Powell and Clark Bowers, Dan Hightower had developed an

[38] NUC *Seascope*, March 17, 1972, 1. Each December, hundreds of grey whales make perhaps the longest migration in nature, from the Arctic Ocean to a small inlet on the Pacific coast of the Baja California peninsula, to mate and calve. In 1857, Charles Melville Scammon arrived in the brig *Boston*, initiating the whaling industry here. Over the next several years, he returned, as did other ships, but based on their depredations, the volume of barrels of whale oil dropped precipitately, and the winter of 1872-73 was the last time it was visited. Scammon's name remained connected to the inlet for decades. Now the largest saltworks plant in the world is located there, on what is known as *Laguna Ojo de Liebre* (Eye of the Jackrabbit Lagoon).

[39] Sam Ridgway email to Tom LaPuzza, July 6, 2020.

Independent Exploratory Development proposal to join the first move of personnel from China Lake to Hawaii. Initially, his ocean engineering efforts under that proposal were directed specifically at supporting the marine mammal work. As Dr. William B. McLean had recognized and often discussed, however, his engineers did not stand on their laurels. They continually challenged themselves and each other with new concepts they pursued into hardware. Thus, the early work at China Lake on the submersible vehicles *Moray* and *Deep Jeep* surfaced at Kaneohe Bay in the form of potential new undersea capabilities. Complementing Hightower as one of the leaders in that was George Wilkins.

Wilkins, a physicist with a master's degree from Oregon State, had worked at China Lake for almost a decade, attaining "national recognition for his contributions in infrared and ultraviolet instrument design and calibration."[40] Additionally, he had contributed significantly to the Deep Submergence Systems Project, serving as one of the group which spent several months of concentrated effort developing the Deep Ocean Technology Technical Development Plan.

When McLean promoted Howard Talkington to department head, he assigned him a Hawaii Division, which Wilkins headed for several years in an acting capacity while Don Moore was on temporary duty in Washington, D.C.[41] Typical of a China Lake engineer, and probably required of all those on the small roster in Hawaii, Wilkins continued to pursue his technical work while he managed an atypically small division. (For much of its history, the Naval Information Warfare Center Pacific and its predecessors supported technical divisions on the order of 75 to 125 personnel. At that time, that was about twice the total number of Hawaii Lab employees.) By mid-1971, Hop Porter had taken over the renamed Ocean Systems Division, allowing Wilkins to resume full-time pursuit of his technical career, specifically researching use of various materials for underwater applications. As noted in Wilkins' retirement letter three decades later,

> Your foresight in realizing the potential for fiber optics to overcome the inherent limitations of coaxial cables led to the establishment of a small group of engineers and technicians who developed and deployed the first long-haul undersea fiber optic cable system. You have designed the cable systems for the optical towed arrays, surveillance communications, and most recently the cable for the undersea vehicle which photographed the *Titanic*.[42]

---

[40] "Floating City survivor retires; completes 31 years of service," NOSC *Outlook*, January 23, 1987, 2.
[41] NURDC *Seascope*, August 8, 1969.
[42] NOSC *Outlook*, January 23, 1987, 2.

Additionally, Wilkins was responsible for one of the breakthroughs that would establish the Hawaii Lab in that position of ocean engineering leadership McLean had foretold at the lab's opening—the research and experimentation that led to use of a newly developed material as a strength member for undersea cables.

George Wilkins

In a Center technical note, Wilkins and two associates, one of whom was Dan Hightower, wrote:

> Progress is reported on the development, testing and demonstration of a new material, DuPont's PRD-49-III, as the load-bearing member for a new generation of high-strength, low-weight, electro-mechanical cables… Techniques for fabricating PRD-49-III filaments into strength members, and for terminating these members, are discussed… Applications to ocean engineering and to other fields requiring cables or ropes with high strength and low weight, are discussed.[43]

Wilkins' interest in the material was stimulated by efforts to develop a high-strength cable for the Remote Unmanned Work System, discussed in Chapter 12.

---

[43] J.D. Hightower, G.A. Wilkins, D.M. Rosencrantz, "Development of PRD-49 Composite Tensile Strength Members," Naval Undersea Center Technical Note 1126, iii. In a departure from usual Center policy that TNs were working papers not to be quoted in formal publications, TN 1126 was approved for public release. It formed the basis of a presentation at a meeting of the American Society of Mechanical Engineers in Detroit in November 1973.

The engineers noted in their acknowledgments the original suggestion for using what came to be known as Kevlar came from an undersea center associate in San Diego, Dr. Jerry Stachiw. A materials engineer who had transferred from the Naval Civil Engineering Laboratory at Port Hueneme, California, in 1970, Dr. Stachiw's subsequent studies of such varying materials as concrete and glass would have a substantial influence on Center projects in the emerging field of ocean engineering.

The TN 1126 authors also cited Hawaii associate Herb Mummery for his work in cable termination techniques. Mummery played an important role in a field critical to the Hawaii undersea vehicle development, establishing a dedicated testing facility to advance cable technology.[44]

George Wilkins cooperated significantly with the State of Hawaii on marine affairs, serving notably on the governor's task force in that area, and coauthoring a book on the subject titled *Hawaii and the Sea*. He was nominated in 1974 as Hawaii Federal Employee of the Year, and was one of the four employees receiving Navy Meritorious Civilian Service Awards during the first year of operation of the Naval Ocean Systems Center. (As will be detailed in Volume II, NOSC made use of an existing Navy award to provide "Center-level" recognition for its first year, until management had time to replace similar awards annually presented at the Naval Electronics Laboratory Center and Naval Undersea Center.)

Environmental science initiatives

While Wilkins and his associates were making a name for the Hawaii Lab in cable technology, others were doing the same in a radically different area: environmental science. Dr. Evan C. Evans III headed the Marine Environmental Management Office, part of the Bio-Systems Division. With others from the division, Evans launched the office's first major project, a biological survey of Pearl Harbor, conducted between mid-May and mid-June 1971. (Shortly prior to this, the Chief of Naval Material had designated the Naval Undersea Center as the Navy entity responsible for "inshore and nearshore marine environmental studies."[45]) The survey team published a report describing biological communities

[44] "Hawaii Facility Testing New Undersea Cables," NUC *Seascope*, January 10, 1975, 1.
[45] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*,

inhabiting all the major lochs of Pearl Harbor, the first such report in three decades.

The following summer, Secretary of the Navy John Warner initiated his new Environmental Protection Award to recognize Navy and Marine Corps commands demonstrating leadership in the environmental arena. The Pearl Harbor study was highlighted as "the most significant breakthrough by a Naval research and development activity during the year related to the Navy's environmental problems."[46] As the principal author of the study, Dr. Evans accompanied Commander William J. Gunn, NUC commander at the time, to receive the award.

Over succeeding years, Evans expanded his efforts, leading in 1974 to a joint program with the Hawaii Institute of Marine Biology (HIMB) to "determine the environmental effects of siltation, dredging, sewage disposal and ship movements on communities of marine organisms characteristic of Hawaii's harbors and reefs."[47] Sponsorship was provided to the Hawaii Lab by the Naval Facilities Engineering Command and the Office of Naval Research, with HIMB funded by the Environmental Protection Agency. Program focus was identification of "bio-indicator systems," marine organisms that showed predictable reaction to various environmental stressors, reaction that could be measured by scientists. Rather than introducing foreign chemical elements into waters under study, the scientists investigated the actual inhabitants of those waters to determine whether stressors such as pollution, reduced oxygen levels, and ship operation were adversely affecting the environment. The state agency had operated a continuous-flow holding system at Coconut Island in Kaneohe Bay to "calibrate" bioindicators since 1970, in waters characterized by high nutrient levels. NUC biologist R. Scott Henderson supervised design and construction of a similar facility near the Hawaii Lab on the Mokapu Peninsula, at the foot of the extinct Ulupa'u volcano: "The ultimate product will be a rapid and reliable survey procedure for assessing and subsequently protecting the marine environment of harbors used by the Navy."[48]

Office efforts included study of the interaction of ship movement and concentration of heavy metals in bottom sediments. It had been theorized passage of ships stirred the water column in shallow harbors (specifically Pearl Harbor and Apra Harbor in Guam) sufficiently to reduce heavy-metal concentrations in some

---

104.
[46] Naval Undersea Center Command History, 1 July 1971 through 30 June 1972, 22-23.
[47] "NUC, HIMB Conduct Joint Research Project in Hawaii," *Seascope*, November 15, 1974, 1.
[48] *Seascope*, November 15, 1974.

marine organisms: "Further research at Ulupa'u is expected to determine the full extent of these effects for possible utilization in improved harbor management."

First Hawaii Department head

While the environmental studies were progressing, the Hawaii Lab experienced an important organizational first: a new department, the Biosystems Research Department, was established, formed principally from the former Bio-Systems Project of the Undersea Surveillance and Ocean Sciences Department, with Bill Powell as department head,.

Fairly early on in his career, Bill Powell was told by his technical director, Dr. William McLean, that he wanted him as a department head. Powell realistically objected, as he had when McLean told him he had the authority to promote a GS-7 employee to GS-14. (Powell's objection to that was backed up emphatically by the personnel officer.)

Powell, asked by McLean to take the position he himself recommended should be a GS-14 at a substantially lesser grade level, noted with surprise his rapid advancement after that: "I don't think an hour ever passed from the time I was eligible before I got the next promotion."[49] He accepted the marine mammal oversight position at Point Mugu, and then volunteered to set up the Hawaii Lab. During subsequent discussions, McLean advised he wanted Powell to be one of his department heads. The latter pointed out the glaring inconsistency between the substantial engineering degrees from highly accredited universities (MIT, Caltech, USC, Cornell) held by the individuals currently in those positions and his own general education degree from Los Angeles City College. He noted to McLean, "They have experience with these roles. These are not the characteristics I have, or share." McLean's response: "That's why I want you to be a department head! I want something that's different."[50]

(One of his fellow department heads, Dr. Frank Gordon, had a similar experience with McLean in his early years at the lab. Asked by the technical director to manage a submarine-related program, Gordon professed honestly he

---

[49] Bill Powell interview, 13.
[50] Bill Powell interview, 54.

had never even been on one and was thus unqualified. He was told by McLean that “he already knew the answers he would get if he gave it to more experienced people and he wanted new ideas.”)

Bill Powell

Powell was thus asked a second time by Bill McLean to take on a major position for which he questioned his own qualifications. McLean himself, in addition to his profound technological accomplishments, had an uncanny capability of sensing leadership potential in individuals who failed to observe it themselves. Powell, who years later during his oral history interview repeatedly expressed a sense of bewilderment at his advancement in federal service, and at a highly technical Navy laboratory no less, would be highly esteemed for his leadership qualities by almost every person who ever worked for him, thus, confirming that McLean capability.

On July 1, 1973, Bill Powell, who would receive the Navy Distinguished Civilian Service Award in a few days, became the first Hawaii department head.[51]

[51] “Powell To Head New Technical Department,” *Seascope*, July 6, 1973, 1.

The cited article provided a brief statement of the department's establishment, with a listing of and some detail on the six major functions assigned, and the statement that Powell's former organization, the Bio-Systems Project of the Undersea Surveillance and Ocean Sciences Department, had been disestablished and all the personnel moved into his new department. That included marine mammal people in Hawaii and San Diego; the latter were both Naval Missile Center and former Naval Ordnance Test Station personnel who had been transferred from Point Mugu. Also included in the new department were the former Navy Electronics Lab acousticians who still occupied NELC buildings Topside on Point Loma. The latter, transferred from NEL in the 1967 West Coast Navy lab reorganization, had been assigned to his division in mid-1972, the first time in the organization's history a large number of technical personnel in San Diego worked for a manager based in Hawaii.

Ocean engineering, undersea vehicles

In addition to the marine mammal work, the responsibilities of the new Biosystems Research Department included the environmental studies conducted by Evan C. Evans and his associates, development of new energy sources and storage capabilities, and human factors. The latter effort was tasked to "Conduct research on human performance in the naval environment and undertake exploratory and advanced development on methods and technology to improve performance of naval systems."[52]

Not included in the mission of the department was much of the ocean engineering work that had grown substantially from Dan Hightower's initial Independent Exploratory Development proposal. Even in the desert, Bill McLean had stimulated his engineers to work on undersea vehicles. As the technical director no doubt anticipated, the Hawaii venue, with its immediate access to the sea, supercharged the effort. Among those engaged in that field and interested in moving to the islands very early on were two young "local" Pasadena engineers, who arrived in Hawaii in 1968, project in hand. One of them, Alvah T. "Tom" Strickland, recalled the project was an essential element of the transfer: "We were talking to the people who were setting up the Hawaii facility, and that would be

[52] *Seascope*, July 6, 1973, 1.

Don Moore and others… and they said, 'Well, you can come to Hawaii but you have to bring your own project.'"[53]

Strickland, a 1964 graduate of Washington State University with a bachelor's degree in mechanical engineering, had subsequently undertaken graduate studies at California Institute of Technology and earned his master's. Shortly thereafter, he arrived at the Pasadena Lab, a few miles east of Caltech, somewhat coincident with Norm Estabrook, a 1963 general engineering grad of UCLA.

Estabrook's first project after his Junior Professional tours was the Buoyancy Transport Vehicle. Initiated at the Pasadena Lab as part of the Large Object Salvage System (LOSS), the BTV was one of the major components of the Deep Ocean Technology (DOT) Technical Development Plan. LOSS was designed for recovery of massive objects from the seafloor, such as a stricken submarine. As may be recalled from Chapter 9, a series of cascading events initially stimulated by the loss of the nuclear submarine USS *Thresher* in 1963 led to the DOT plan. It was reasonable, given the initial stimulus, the plan would include some means to recover a lost submarine that, unlike *Thresher*, had bottomed out above crush depth, so presumably the boat was intact and the crew still alive. The plan included, as will be detailed in a later chapter, a capability to rescue the crew without the daunting effort of recovering the submarine.

The BTV was basically a diver-operated underwater forklift to support LOSS personnel moving heavy objects underwater. It was also designed to transport as many as six divers, and as a portable power source for hydraulic tools.[54] Estabrook, the inventor and project engineer, and Strickland, responsible for vehicle subsystems, moved with their project to Hawaii in August 1968. Although they were provided a reasonable workspace, their new facilities had shortcomings:

> Well, we were in half of a hangar, one of the hangars that was built sometime before World War II and it was interesting. When we first got out there… We didn't have any facility support, so we were cleaning our own bathrooms and washing windows and everything. It was really a rag-tag group. But there were no rules. And we found that very useful when it came to being able to get things done. I think that's one of the reasons Bill McLean wanted to set up the lab out there. He was a guy who was intimately familiar with getting things done by going around the rules rather than acting in accordance with them.[55]

---

[53] SSC Pacific oral history interview of Alvah T. Strickland conducted by Tom LaPuzza, June 5, 2012, 4.
[54] "NUC Hawaii engineers design undersea forklift," *Seascope*, August 28, 1970, 1.
[55] Strickland interview, 4.

As they had done in Pasadena, and as Center engineers tended to do all the time, Strickland and Estabrook proceeded despite the challenges and completed the project. The fully functioning BTV was transferred subsequently to the Naval Civil Engineering Laboratory at Port Hueneme, California, for use in their underwater construction program.

Estabrook moved on to manage development of the Launch and Recovery Platform, a submersible designed to minimize potential damage to underwater vehicles during those critical operational phases. It is one of several Hawaii-developed submersibles covered in the next chapter and in Volume II, including:

--*Makakai*, a 600-foot-depth manned submersible which included an acrylic plastic pressure hull providing unlimited visibility for operator and passenger

--Remote Unmanned Work System (RUWS), a 20,000-foot work vehicle developed under project manager Dan Hightower

--Advanced Tethered Vehicle (ATV) system, another abyssal-depth work vehicle developed by a team led by Terry Hoffman

--Submersible Training Platform (SUBTRAP), a LARP-like device created by former Navy SEAL and ultra-triathlete Ron Seiple to provide an inexpensive training platform for his brothers-in-arms—Navy Special Forces personnel

Stable Semi-submerged Platform

With conclusion of the BTV project, Strickland moved on to play an integral role in one of the most significant Hawaii projects, the Stable Semi-submerged Platform (SSP), stimulated by early hydrodynamics studies of Dr. Tom Lang.

Lang, it will be remembered from previous chapters, was a Caltech graduate (at age nineteen) who went on to earn multiple advanced degrees, including a Ph.D. Generally regarded as the Underwater Ordnance Department's expert in hydrodynamics, he was featured in several Naval Ordnance Test Station *Rocketeer* newspapers reporting on his efforts in designing hydrofoils and related surface and undersea craft on his own and with his father. He was also instrumental in the initiation of Navy use of marine mammals, studying dolphins in the unsuccessful hope of learning hydrodynamic secrets from them.

Building on the concept of the hydrofoil, Lang invented a vessel he called the Semi-Submerged Ship. The design featured a sort of catamaran, with two fairly sizeable, torpedo-shaped hulls that ran submerged and were connected by four vertical struts to a platform above the water's surface. The submerged hulls would provide stability as well as a large capacity for fuel and cargo, and the above-water structure offered a variety of promising uses, including weapons platform, cargo carrier, passenger and vehicle ferry, aircraft landing platform. The fact the spindly struts were the vessel's only contact with the air-water interface substantially reduced wave action against the hull, almost eliminating wave-induced motion. Contributing to its stability were controllable canard fins located on the bow struts and a cross-stabilizing fin with controllable flaps near the stern struts.

The generic name eventually applied to this and similar designs was Small Waterplane Area Twin-Hulled, or SWATH ship. Increased service interest in potential benefits of such designs resulted in the establishment of a Navy SWATH program by Naval Ship Systems Command in 1972.

Lang's associates built a radio-controlled five-foot model to evaluate his design concept, testing it in the same commercial towing tank in which dolphin swimming velocities had been studied (by Dr. Lang as a matter of fact) and operating it in San Diego Bay behind Bill McLean's office, where it wowed VIP visitors of the technical director.[56]

The stimulus for a sea-worthy vessel stemmed from an urgent requirement for a stable platform from which to conduct engineering tests of vehicles and equipment in the rough waters surrounding the Hawaii Lab, where project testing (and human performance) required a certain modicum of stability. With sponsorship from the Director of Navy Laboratories, design began in March 1970 on what would become a 190-ton ocean-going model.

Dan Hightower managed the project initially, simultaneously leading development of the Remote Unmanned Work System. In the very early days of the Hawaii Lab, the number of employees was small and there was substantial multitasking. As time proceeded, however, reality crept in: only in significantly unusual circumstances could an engineer manage two major projects at the same time. Center Deputy Technical Director Doug Wilcox told Hightower he could manage one project, but not two. The management of the SSP went to Hop Porter.

[56] *Seascope*, October 1, 1971, 1.

After the BTV was shipped to California, the SSP project provided Tom Strickland his next work assignment, as chief engineer for design and construction. He reported,

> We didn't have nearly the manpower at our lab to do this size project, so we went to Pearl Harbor and talked to the …design superintendent, who made some of his design crew available to us. We essentially moved the project office over to Pearl Harbor…to complete the design of the ship.

Hawaii Lab employee Norm Kelsey had worked previously for the Bureau of Ships and understood the appropriate procedures for drawing a set of ship plans. Strickland admitted,

> Without his assistance and guidance, I would never have been able to put this project together. Norm showed us how to organize the drawings, how to reference one thing to another, how to make notes on the plans, everything… In most cases ship plans are pretty general when they come to the shipyard… We had spelled out every nut, bolt, and washer along with where to purchase it.[57]

Despite the attention to detail, there were difficulties. Naval Ship Systems Command (NAVSHIPS) was the Navy organization responsible for ship design and construction, and it was decidedly reluctant to delegate that responsibility.[58] NAVSHIPS had its own designated lab, the Naval Ship Research and Development Center (NSRDC) in Maryland, which it relied on for the obvious R&D required before construction of a new ship, particularly a radical new design of ship, could be initiated. Before he had transferred management of the SSP project to Hop Porter, Dan Hightower had worked diligently with NAVSHIPS and NSRDC to get the platform approved for construction.

Final hurdle: "Curves of form"

The project's final hurdle was determination of "curves of form," requiring a highly technical study to determine stability of a proposed new ship design. "I was willing to fund NSRDC to do it, but they didn't know how," Hightower said. Fortunately, one of the people on his staff did. Harry Chalmers, a graduate of the

---

[57] Strickland interview, 10.

[58] The organization dated back nearly the entire history of the U.S. For a century, it functioned as the Bureau of Ships, until the 1966 reorganization, when the Navy replaced its bureaus with systems commands. A few years after the SSP controversy, in 1974, it became Naval Sea Systems Command, that name continuing to the present (2020).

U.S. Coast Guard Academy and a Coast Guard service member for some time, had resigned his commission and gone to work at the Hawaii Lab. Based on his training and experience, he was confident he could provide the appropriate documentation. His two requests were that he be allowed to work at home and he be left alone until he finished. Hightower agreed. Chalmers indeed worked on the effort at home; at the end of long weeks of studying and calculating he had the information which, when submitted to NSRDC, satisfied the final requirement for approval of SSP construction.[59]

With the landing of a Navy helicopter aboard in 1976, the Hawaii Lab's Stable Semi-submerged Platform (SSP) *Kaimalino* became the world's smallest aircraft carrier.

What Tom Strickland and the Pearl Harbor team had designed, with substantial long-distance technical support from Tom Lang and other undersea

[59] Dan Hightower phone conversation with Tom LaPuzza, January 16, 2019.

center personnel from San Diego and Hawaii like Kelsey and Chalmers, was a unique combination of surface and subsurface craft eighty-nine feet long, forty-six feet wide at mid-section, and thirty-two feet high. Six-and-a-half-foot-diameter cylindrical twin hulls ran the length of the craft about half a dozen feet underwater, providing ballast for stability and large cargo storage spaces. The hulls and vertical struts were fashioned of high-tensile steel, with the latter supporting and tied together by an aluminum cross structure riding some twenty feet off the water.

Significant among the unique design features was an end cap for one of the hulls, a seventy-eight-inch-diameter supersized "viewport" of six-inch-thick acrylic plastic. Cast commercially under the watchful eye of Center materials expert Dr. Jerry Stachiw, the five-thousand-pound hemisphere was then machined and shipped to Hawaii for eventual attachment to the SSP. Visitors to the Hawaii Lab who considered a cruise on the SSP to be a major thrill ride would be blown away by crouching in the dome and watching the underwater world pass by in panoramic splendor.

Before those rides and views could be enjoyed, however, the craft that had been meticulously planned had to be built. With the design plans complete, Center personnel approached the Coast Guard shipyard at Curtis Bay, Maryland, about construction. Strickland called the resulting relationship "very fortuitous," in that no lengthy commercial contract specification and awarding period was necessary, and of the "probably five, six, seven hundred change orders, not one of them had a change in cost associated with it."[60]

Strickland moved to Baltimore for a year and a half, spending busy days overseeing the construction as it progressed. Shipyard workers, accustomed to working on buoy maintenance and similar routine matters, enjoyed the challenge of the project, and the shipyard assigned its best personnel to it, he said.

Another unique characteristic of the craft was the propulsion system, required by the design: "We had gas turbine engines installed in the upper hull and needed to get three thousand horsepower down to the propeller shafts some twenty-one feet below," Strickland explained. A consultant from the Naval Air Test Center at Naval Air Station Patuxent River, Maryland, designed a four-tier chain drive to power the vessel. While it provided the necessary connection between the driving force and the propellers, it also presented some difficulties, described below.

[60] Strickland interview, 11.

In October 1973, the vessel was launched, making its maiden voyage around Curtis Bay. The Center newspaper ran a lengthy story introducing the craft to employees for the first time (at least those in San Diego).[61] The article included a detailed description of the craft and plans for its intended use. It also explained the name with which SSP was christened, *Kaimalino*, a Hawaiian word meaning "calm water," more or less the expectation for the craft.

Shortly after it was launched and began trials, one of the propeller shafts broke, setting off a chain reaction of events that started a fire. The results could have been catastrophic, had not the Coast Guard firefighting team reacted quickly and extinguished it. Strickland, who had already returned to Hawaii, was sent back to investigate and move the project forward.

"It didn't take too long to determine that the problem had been fatigue failure in the shaft that broke," he explained. "I instructed the yard to pull the complementary shaft on the other side and inspect it for fatigue cracks. They pulled it and there was a big crack."[62] He ordered all the shafts pulled, and found fatigue cracks in seven of the eight. Based on that sobering thought, he redesigned the chain drive system using "all the state-of-the-art aircraft design techniques available" and solved the problem.

With the new propulsion system in place and damage repaired, local trials were completed and the SSP was ferried aboard a Military Sealift Command ship to Hawaii in the spring of 1975. It began more comprehensive sea trials and actual use by Hawaii project people as a platform for operation of submersibles.[63]

In the fall of 1976, *Kaimalino* demonstrated its remarkable stability, as it became the smallest ocean-going platform to serve as an "aircraft carrier." Navy, and later Coast Guard, test pilots landed helicopters aboard the vessel as it steamed through Hawaiian waters at various speeds in varying sea states. The pilots were "enthusiastic" about landing on SSP.[64]

Most critical was the fact SSP *Kaimalino* made it possible for island personnel to conduct tests of their developmental products despite the huge swells characteristic of the Pacific in and around their lab. According to a contemporary

---

[61] "SSP Operating On Curtis Bay," *Seascope*, November 9, 1973, 1.
[62] Strickland interview, 14-15.
[63] James A. Kallio, "Seakeeping Trials of the Stable Semi-Submerged Platform (SSP) Kaimalino," David W. Taylor Naval Ship Research and Development Center, April 1976.
[64] Dick Brady, "Air Capability Trials in Hawaii," *Seascope*, October 8, 1976, 3.

article in *Popular Mechanics*, "she can easily navigate the stormy seas of the Molokai Channel… without even spilling a drop of coffee from a cup resting on a pilot-house window sill with seas running to heights of 12 feet."[65]

Staking a claim to the future

In 1972, the undersea center celebrated its fifth anniversary as a Navy laboratory on Point Loma, with a new name (both the earlier "Warfare" and the subsequent "Research and Development" modifiers had been dropped in favor of the simplified Naval Undersea Center), and new commanders. (Commander Bill Gunn relieved Captain Charles Bishop for a few months, and then the designated commander, Captain Robert H. Gautier, relieved him in the fall.)

Hawaii Lab Director Jesse Burks armed with flags to lay claim to more Marine Corps Air Station Kaneohe Bay property for lab use.

A combination hail-and-farewell and anniversary party was held in San Diego, with Technical Director Dr. William McLean summarizing the substantial achievements of the five-year period, highlighting the introduction into the fleet of two operational marine mammal systems by the Hawaii Laboratory. In addition to a serious award—the first presentation of the Center's new Lauritsen-Bennett Award to weapons department head Chuck Beatty—there were also some humorous presentations, one to Hawaii Lab director Jesse Burks. Acknowledging

[65] Larry Wood, "New mini flattop 'flies' like a plane," *Popular Mechanics,* January 1978, 62–64 and 130.

his ability to identify land on the Marine Corps air station that would be valuable to the undersea center, and then somehow gain Marine support to allow usage of it, retiring Center commander Captain Charles Bishop presented Burks a couple of pennant-shaped flags with "NUC" on them to plant in the ground in Hawaii to lay claim to more of that land.

Indeed, one needed to look no further than the *Seascope* issue announcing the change in command title and mission to understand the substantial physical improvements made by Burks and company during the less than five years of lab operation.[66] A pier and holding enclosures for marine mammals had been constructed, as had laboratories and shops in the hangar originally assigned to the handful of Hawaii Lab pioneers. Acquisition of four buildings on twelve acres of land followed, the result of Pacific Missile Range personnel vacating and moving to Barking Sands on the island of Kauai. (In an interesting coincidence, Naval Undersea Center torpedo development personnel would make use of Barking Sands Tactical Underwater Range on a regular basis for weapons testing.) One of those structures acquired, Building 1181, would become, and remain, the Hawaii Lab's headquarters. With the steady growth of the lab workforce, fourteen prefabricated buildings were erected; six more, the article said, had been ordered and would be placed in a spot indicated in an accompanying aerial photo. A permanent laboratory building had been requested through appropriate channels.

Project work was booming, as the swimmer defense dolphins had returned after a successful deployment to Vietnam the previous year, and the manned submersible *Makakai* was conducting its first diving tests after formal launch.

Burks would continue to manage Hawaii administrative matters skillfully for almost ten more years so the technical department and divisions could go about their business of fielding new technologies and capabilities. He retired in 1980, after a full thirty-year career in uniform followed by a dozen more as the Hawaii Lab director. During that time, his stake-claiming flags had changed from "NUC" to "NOSC" when the Naval Ocean Systems Center was established in 1977.

Also during that time, a fair number of people and much of the Bill McLean notion of "creative environment" would migrate west from the California desert and the city of Pasadena to the shores of Kaneohe Bay. With that would come the camaraderie and socialization characteristic of China Lake. The small-town

[66] *Seascope*, June 23, 1972.

atmosphere, in which there were no strangers, was prominent. Carmela Keeney, second-longest serving technical/executive director in Center history to Bill McLean, but initially a working-level engineer at the Hawaii Lab, commented: "Everybody knew everybody. They were very supportive of each other, collaborative, hardworking, focused on high-quality research and development and getting things out to the user. So it was great; it was a great experience."[67]

In return, Hawaii would add its flavor to the mix, with pig roasts and croquet tournaments replacing China Lake's cocktail parties. Work was accomplished with little of the long-sleeved-white-shirt formality of the Pasadena Lab. Hawaii employees might wear a coat and tie to attend meetings with Washington sponsors; otherwise, the dress code was shorts, Hawaiian shirts, and flip-flops.[68]

The story of the substantial accomplishments over the next decade and a half of the unique entity known as the Hawaii Lab will be related in Volume II.

Dr. Whit Au

Whitlow W.L. Au was an infant living in Honolulu in 1941 when Pearl Harbor, less than a dozen miles away, was attacked. He grew up and was educated in Honolulu, transitioning from high school to college as the islands transitioned from territory to statehood in 1959. After earning an electrical engineering degree from the University of Hawaii, he departed for the mainland to pursue a master's degree at Washington State University. He then served in the U.S. Air Force, studying radar signal propagation of space vehicles re-entering the atmosphere. Following his service, he returned to Washington State, earning a Ph.D. in electrical sciences, focusing on wave propagation and ionospheric physics.

Hired by the Naval Undersea Center in 1971, he worked initially in San Diego

---

[67] Carmela Keeney, SSC Pacific Executive Director, interview with Tom LaPuzza, September 19, 2016.

[68] *Seascope* editor Tom LaPuzza, visiting the lab in August 1974, unknowingly wore a coat and tie the first day. After discovering his "mistake," he purposely wore them the other four days, because lab employees were constantly approaching, asking if they could assist or provide directions, a perfect way to meet people and set up newspaper story interviews.

for undersea surveillance pioneer Dr. Hank Aurand. By the beginning of 1972, however, he was back home in Hawaii, working with marine mammals. Au's interest focused on basic research, specifically on the intricacies of their biological sonars. Within a few short years his research resulted in a foundational paper suggesting dolphins (specifically Atlantic bottlenose) possess a much more sophisticated sonar than had been thought previously:

> These open-water sound pressure levels [of *Tursiops*] are at least 30 dB higher than any click-source levels reported in the literature… The typical clicks had average duration of 40 [micro] seconds, with peak energies between 120 and 130 kHz, much higher than the previously reported energy peaks centered at 35 to 60 kHz.[69]

A December 1983 *Outlook* article reported those findings initially met with skepticism in the scientific community, delaying acceptance for publication and requiring "rechecking his results and redescribing his procedures until finally his data were accepted as valid."

A critical feature of the research, stated in the opening paragraphs and specifically cited in the concluding one, was that preceding testing had been done in tanks, while Au and his associates studied dolphins in their natural environment, in this case Kaneohe Bay. Difference in the data compared to environmental differences prompted the researchers to suggest "the animals possess an adaptive click-shaping capability over a relatively large frequency range. They are able to optimize the signal characteristics to best perform a given echolocation task."

Buried in that statement is a wealth of information and implications about the Marine Mammal Program itself, particularly as originally envisioned by Bill Powell, about working cooperatively with the animals and maintaining them in the ocean versus a tank. In the case of the sonar research of Whit Au and others, it allowed studying behaviors and capabilities of the animals they would not, or could not, demonstrate in the closed environment of a tank.

The citation for a 1980 department award acknowledged his "international reputation" for dolphin sonar research, noting his development of hardware to reproduce echolocation signals mimicking dolphin sonar pulses. In another half-dozen years, he received the Navy's third highest honor, the Meritorious Civilian Service, for his contributions to development of the Bionic Sonar Program. His

---

69 Whitlow W.L. Au, Robert W. Floyd, Ralph H. Penner, and A. Earl Murchison, "Measurement of echolocation signals of the Atlantic bottlenose dolphin, Tursiops truncatus Montagu, in open waters," *Journal of the Acoustical Society of America*, Vol. 56, No. 4, October 1974, 1280-1290.

achievements "greatly assisted…the development of all future Navy sonars, particularly for use in high noise and high reverberation environments."[70]

Au was selected for fellowship in the Acoustical Society of America in 1990, cited for his internationally recognized research into dolphin acoustic signal processes.

Whit Au's research with Hawaii dolphins resulted in a foundational paper on the mammal's highly sophisticated biological sonar.

His landmark book, *The Sonar of Dolphins,* was published in 1993, also his last year with the Center. The Hawaii Lab closed that year. In its final months, the Hawaii native son was cordially invited to move to San Diego and continue his

---

[70] *Outlook,* August 22, 1986, 1.

research with Navy dolphins; he chose to remain at home. With his associate Dr. Paul Nachtigall and several former Navy dolphins, he instead established a relationship with the University of Hawaii, Manoa, whereby his basic research could continue at Coconut Island, near the former Hawaii Lab. For several decades he also trained graduate students in the nuances of marine mammal acoustics.

He became the third member of the Point Loma lab family elected to the presidency of the Acoustical Society of America, following Dr. Robert W. Young and Robert S. Gale, serving the 2009-2010 term. The society would heap well-deserved honors on Whit Au. In saying good-bye to him, the society's "Acoustics Today" obituary noted in addition to his several books, he had published 226 papers in peer-reviewed journals, concluding: "It is hard to imagine where the science of the echolocation of dolphins and whales would be today without the contributions of Whitlow W.L. Au."

12

Diving into the Depths

"One hell of a cheer went up from the ship," said Bob Watts, recalling at a San Diego airport press conference the moment a few days earlier he and an unlikely collection of individuals and equipment stood on the heaving deck of the Canadian Coast Guard Ship *John Cabot*, watching as a small submersible popped to the surface of the Irish Sea and two men emerged, alive and well.[1]

Cabot, built as a combination icebreaker and cable layer, was involved in the latter role supporting the laying of a telephone cable from Ireland to Nova Scotia in the summer of 1973, operating about a hundred miles southwest of Cork, Ireland. (Students of disasters may recall Cork as the last port of call before the RMS *Titanic* headed out for its rendezvous with an iceberg.) Also supporting that project was the two-man submersible *Pisces III*, one of several such vehicles operated by Vickers, Ltd., a British engineering company. Through a set of disastrous events, the hatch cover for the after-machinery compartment of *Pisces* was ripped off, and the compartment rapidly filled with water, sending the craft plummeting backward into the depths. It struck bottom and lodged deeply into the mud 1,375 feet below the surface. The two men aboard had approximately seventy-two hours of air. Although Vickers had some assets in the area, including two *Pisces* sister subs, company officials wisely sought backup assistance from the U.S. Navy.

The Naval Undersea Center command duty officer received a call August 29 at 0445 (4:45 AM), requesting that assistance. As related by Howard R. Talkington, head of the NUC Ocean Technology Department, several hours later the team for the Center's Cable-controlled Underwater Recovery Vehicle (CURV

[1] Naval Undersea Center *Seascope*, September 14, 1973, 2. A footnote in Chapter 10 noted the name changes associated with the undersea center. *Seascope* was that center's newspaper, whose title remained during its publishing history (1968-1977). In the citations below, the center's name will be accurately (if perhaps confusingly) noted for each specific issue cited—Naval Undersea Warfare Center (NUWC), Naval Undersea Research and Development Center (NURDC), and finally Naval Undersea Center (NUC).

III) was requested to "prepare… for soonest departure."[2] In less than six hours, the CURV vehicle, its control van, cable, and support equipment were ferried across the San Diego harbor entrance channel to North Island Naval Air Station, where the U.S. Air Force already had landed two huge C-141 Starlifter aircraft for the nonstop flight to Ireland. The aircraft arrived at Cork in the early evening of August 30. The CURV vehicle, equipment, and crew were barged downriver (required by the low tide), where the *John Cabot* awaited to carry them to the accident site; they arrived twenty-four hours later.

While the expeditious transport from America was underway, the two *Pisces* sister craft had arrived onsite, but, Talkington noted, were unable to carry down a line heavy enough "to provide a fair safety factor when lifting the great load from a pitching and heaving platform… The seas were running high and a strong wind was blowing, making the operations most difficult."

A fair indication of what CURV primary operator Larry Brady later stated was "probably a Sea State Six" was the fact the deck of the *John Cabot*, thirty-five feet above the surface, was inundated with waves, one of which shorted out CURV's control cable tether. The crew quickly cut the cable and wired it directly into the control console in the operations van, where Brady, who had operated CURV I in the recovery of a hydrogen bomb from the Mediterranean in 1966 (detailed below), was setting up to retrieve a substantially more important target.

Based on the human lives at stake, CURV III was launched in Sea State Six to carry a recovery line to the seafloor 1,375 feet below. Several hours later, *Pisces III* surfaced, its two-man crew alive and well.

---

[2] Howard R. Talkington, "The U.S. Navy Participation in the Rescue of the Pisces III," Marine Technology Society Journal, Vol. 8, No. 1, January 1974. Talkington had overseen the CURV I recovery of the hydrogen bomb from the Mediterranean seven years earlier.

As will be discussed in more detail later in this chapter, one of the most dangerous actions in the life of any submersible is getting it over the side of the support ship and into the water. The rolling and pitching of the support ship, with a submersible dangling from a crane line over the side and swinging erratically, will almost certainly dash the vehicle into the ship's hull. With the heavy seas running that morning, ordinary circumstances would have dictated not even trying to launch CURV.

Brady reported afterward, "The seas were just tremendous, and we wouldn't normally launch in this kind of sea condition, but because of the human life involved, we launched."[3]

To attach the required heavy line to the stricken sub, Vickers personnel had jury-rigged a "toggle bolt" of one-inch metal plate, with a crescent wrench welded

The CURV III team received numerous awards for the Pisces III rescue, including one from the Chief of Naval Material, presented by Deputy CNM Rear Admiral Frank C. Jones. Shown are (l-r) Lieutenant Commander Christo Dimolios, Denny Holstein, Larry Brady, Admiral Jones, Bob Watts, John DeFriest, William Sanderson, and Tom Wojewski.

[3] "CURV Crew Home After Rescue," NUC *Seascope*, September 14, 1973, 3.

on and attached with bungee cords to ensure once inserted into the *Pisces* hatch the toggle would deploy. That wasn't the only jury-rigging. The deck inundation that shorted out the control cable also disabled CURV's on-board compass. That problem was solved by attaching a diver's wrist compass to one of CURV's runners, in sight of one of the vehicle's closed-circuit TV cameras.

When it became obvious the line attached to the stricken sub was problematic in pulling it out of the bottom mud and bringing it safely to the surface, the CURV crew was asked to dive the vehicle. In less than an hour CURV was on the bottom, *Pisces* located, and the toggle successfully engaged. The lift with one of the *John Cabot*'s winches began immediately, and in less than three hours *Pisces* was on the surface, with divers in the water attaching securing lines and opening the personnel hatch. The two survivors emerged, undoubtedly drained and exhausted, but also certainly alive.

Rationale for DSSP

It was clearly the moment envisioned when the Navy first made the monumental decision to initiate what it termed the Deep Submergence Systems Project (DSSP), discussed in Chapter 9: saving the lives of sailors trapped in a stranded submarine in waters seemingly too cold and deep and dark for any hope of rescue. Although such a capability would not have saved the crew of the USS *Thresher* (SSN-593), whose loss stimulated DSSP's establishment in June 1964, the concern was the potential for a similar future incident in which a submarine and crew might be resting on a sea floor in five or six hundred feet of water, not implosion depth, but definitely a depth out of range for the Navy's rescue equipment of the time. DSSP was initiated for that eventuality.

Losses of submarines and their crews in peace time were not unprecedented: on December 17, 1927, the submarine *S-4* sank in a hundred feet of water off Provincetown, Massachusetts, following a collision with a Coast Guard destroyer.[4]

[4] *Jane's Fighting Ships 1931* (London: Sampson Low, Marston & Co., Ltd., MCMXXI), 483. An interesting coincidence is that exactly ten years earlier, on December 17, 1917, nineteen of twenty-four crewmen were lost as a result of ramming and sinking of the submarine F-1 by its sister sub F-3 in heavy fog off Point Loma.

Most of the *S-4* crew succumbed quickly, but six remained alive for some time in a torpedo room, tapping out messages of hope that could not be answered; eventually they suffocated when rescuers had no means of saving them. Following a strong public outcry, the Navy established a study group to research various rescue techniques. In addition to submarine modifications to facilitate rescue, two technologies eventually emerged: the Momsen diving lung for saving individual sailors from a stranded sub and the McCann Chamber. The latter was intended for group rescues and was employed successfully in May 1939 when USS *Squalus* (SS-192) foundered off Portsmouth, New Hampshire.

Both devices resulted from design efforts of Charles Momsen, an innovative naval officer who later served in World War II and was accorded the Legion of Merit for on-site redesign of faulty torpedoes that rendered them effective. Several decades earlier, he had stood by helplessly when the sister sub to the one he commanded sank with all hands, some of them his friends. The plans for a diving bell he designed in hopes of preventing another such tragedy languished in a Pentagon in-basket for a year and then were judged impractical. Undeterred by rejection and stimulated by another submarine tragedy, he developed what quickly was nicknamed the Momsen lung, an emergency breathing device designed to provide sufficient air to allow sailors individually to exit a submarine and make it safely to the surface.

Lieutenant Commander Charles Momsen

Momsen and McCann to the rescue

Momsen's previously proposed diving bell, redesigned by Lieutenant Commander Allan McCann and renamed the McCann Chamber, figured prominently in the *Squalus* rescue, in which Momsen commanded the divers and McCann the chamber operations. Of coincidental interest is the fact the trapped crew members had Momsen lungs and had been trained in their use, but the commanding officer considered it too dangerous for his already severely chilled sailors to lock out into the frigid waters and attempt to reach the surface more than two hundred feet overhead. The McCann Chamber was deployed four times and rescued the thirty-three surviving *Squalus* sailors of the crew of fifty-nine.[5]

Thresher's loss put a spotlight on that rescue technology, now almost twenty-five years old and inadequate for potential rescue of a crew of more than a hundred. (The McCann Chamber had a personnel capacity of less than ten and would have required many hours to rescue a nuclear submarine crew, plus it was substantially depth-limited.) Exactly two weeks after the destruction of *Thresher*, the Secretary of the Navy established the Deep Submergence Systems Review Group, with Rear Admiral E.C. Stephan in charge, to address Navy rescue capabilities. According to the report they issued, a massive and classified account in four volumes, "The major goal of the DSSRG has been to conceive operationally reliable systems with growth potential to recover both personnel and objects from the deep oceans."[6]

Chief among the tasks assigned to the group was to "review Navy plans for the development and procurement of components and systems related to location, identification, rescue from, and recovery of deeply submerged large objects from the ocean floor." (They were later assigned additional responsibility to support the Air Force in recovering from the ocean floor components of satellite systems falling from the sky.)

Given their immediate focus had to be the public perception, and in fact the reality of that perception, that the Navy had done little after the submarine disasters of the early twentieth century to improve its capabilities to take care of its own, immediate progress had to be made to change both the perception and the reality. (The Momsen lung and the McCann Chamber had been operational since about

---

[5] *Jane's 1940*, (London: Sampson Low, Marston & Co., Ltd., MCMXL).

[6] *Report of the Deep Submergence Systems Review Group*, NAVEXOS P-2452, March 1964, 2.

1927. Despite decades of the Navy launching numerous, increasingly sophisticated submarines, there was no concomitant effort at modernizing rescue capability.) The group's short-term recommendations were improvement of automatic distress-signal communication by installing updated radio buoys and acoustic beacons on submarines, providing more realistic submarine escape training and updated equipment to submarine sailors, and increasing rescue chamber operating depth.

More challenging was the long-term recommendation, to "develop, construct, and operate a new rescue system consisting of six rescue units of two small submersible vehicles each."[7] Later in this chapter we will discuss the various considerations related to the development and use of manned versus unmanned systems, but at the time the former was selected as the most appropriate: "After much consideration manned submersibles were chosen for the search, rescue, and recovery functions to achieve maximum versatility and reliability under widely varying conditions."

Four focus areas

The review group actually deemed its charter to include four areas of concentration: in addition to the recovery of submarine crews, it considered "Man-in-the-Sea," which resulted in the SEALAB experiments discussed in Chapter 10; ocean bottom study and small-object recovery; and large-object recovery.

Three months after the DSSRG report publication, in June 1964, the Navy established the Deep Submergence Systems Project, under the direction of Special Projects Office head Rear Admiral Levering Smith. Two years later, on February 9, 1966, Rear Admiral Smith spun off DSSP from SPO as a separate entity, placing his chief scientist Dr. John Craven in charge.

Chapter 9 detailed the work of Naval Ordnance Test Station personnel from China Lake and Pasadena to provide focus to DSSP efforts, resulting in the Deep Ocean Technology Technical Development Plan, published May 1, 1968, to concentrate DSSP efforts related to new technology. Ivor Lemaire, one of the principals in the development of that first iteration of the DOT TDP (one of several,

[7] *Deep Submergence Group Report*, 4.

since DoD required annual plans for major R&D programs), recalled:

> …sequentially, the DSSP—PM-11—preceded Deep Ocean Technology. Deep Ocean Technology was kind of an outgrowth. I think that what people decided in PM-11 was that there needed to be a technology effort as well as the hardware effort, which was DSSP. DSSP was focused on salvage and recovery of downed submersibles. Whereas, Deep Ocean Technology was really more stressing, what do you need in the way of technology to go extend that capability to deep depths?[8]

Shortly after its establishment, DSSP published a seventeen-page document outlining the project's background, purpose, and programs, titled "U.S. Navy Deep Submergence Systems Project Fact Sheet." It included the four areas of concentration originally specified by the DSSRG, and added a fifth: development and operation of the nuclear-powered deep-submergence vehicle *NR-1*.

Submarine rescue technology expedited

The Naval Undersea Center (NUWC/NURDC/NUC) and its successor Naval Ocean Systems Center would contribute substantially to the four primary efforts. Its contributions to SEALAB, including the ill-fated SEALAB III, were detailed in Chapter 10. While the concept of manned occupation of ocean depths languished as a result of that disaster, DSSP moved ahead quickly on the submarine rescue concept with development of the Deep Submergence Rescue Vehicle (DSRV). Although the DSSRG had specified "six rescue units of two small submersible vehicles each," the DSSP brochure, in three-plus pages, advised "several" DSRVs were in development.

In a book he wrote several decades later, DSSP chief scientist John Craven dedicated an entire chapter to the subject. Early on, he defined the purpose: "The mission of the DSRV was to rescue personnel from a downed submarine of any nation wherever that emergency might occur."[9] He followed that up with a set of reasons that "realistic assessment revealed that this was for all practical purposes a nonmission [sic]," among them that within a time window of twenty minutes to three hours, dependent upon which U.S. port the sub departed, the submarine would be in waters too deep for rescue. If the emergency occurred before that time,

---

[8] Ivor Lemaire Naval Information Warfare Center Pacific oral history interview conducted by Tom LaPuzza, April 16, 2019, 23.
[9] John Pina Craven, *The Silent War* (NY: Simon and Schuster, 2001), 116.

essentially meaning the continental shelf was still under the sub, rescue capabilities were already in place for that circumstance, according to Craven. (In counterpoint, those capabilities centered around the McCann Chamber, which DSSP was established to replace with something more effective.)

"Why then would we insist on investing large sums of money for the development of a rescue vehicle that in all likelihood would never be used?" he asked his reading audience. Citing the humanitarian desire to rescue other humans from the death grip of the sea regardless of associated difficulties and challenges, he then offered another consideration,

> one that never appeared in a directive but was tacitly understood. There were many highly classified missions associated with national security that could not be accomplished without a DSRV system. The specific operational needs for these missions could not be anticipated but they were certain to occur. Thus, a DSRV designed, constructed, and deployed for every conceivable rescue mission would also be available for the intelligence 'mission impossibles' that were sure to occur.

He was in essence recalling the review group's statement in establishing the DSRV mission:

> Deep submergence systems require frequent and varied use to respond reliably to infrequent, but unpredictable, submarine disasters. To maintain their operational readiness, to contribute more fully to Navy missions, and to help defray the investment, they should be capable of a variety of useful work in the ocean depths.[10]

Given Craven's statement that highly classified missions might come up, and the reality this document cannot discuss those, we will concentrate on the development of the undersea craft for its publicly announced purpose: rescuing sailors. The plan, although complicated in its execution, was fairly simple in its description: an undersea craft (actually, several such of the same design) would be constructed that could be airlifted in a reasonably short time anywhere in the world via military aircraft and from there transported via submarine to the site of a stranded sub. Craven listed some of the details in the brief description: the craft must be small enough that it could be transported, with all necessary equipment, via an existing U.S. Air Force cargo plane, meaning one like a C-141. The transport necessarily would be from the DSRV's home port (San Diego was the first selected) to the closest appropriate airfield (long runway for the huge aircraft and a short distance from a port on the ocean, obviously that ocean and port nearest the site of the downed submarine). Additionally, an appropriate trailering device

---

[10] *Deep Submergence Systems Review Group*, 2.

was needed to transport the vehicle from its base to the departure airfield and from the arrival airfield to the port. From there, the submersible vehicle would be loaded on a commissioned U.S. submarine for transport to the accident site.

To describe the effort in the simplest terms, while recognizing that even in those terms a substantial amount of complex and coordinated effort is required for success: a submarine loses power and through some set of circumstances is stranded on the bottom at depths shallow enough a rescue is possible (above crush depth). It communicates via appropriate emergency communications circuits its condition, and the home port of the DSRVs is notified to execute the rescue scenario (which has been practiced numerous times). An Air Force cargo plane is vectored to the naval air station closest to the DSRV activity (e.g., NAS North Island in San Diego); the DSRV is loaded aboard its specially designed trailer and trucked to that air station. While these actions are underway, the nearest U.S. submarine is ordered to the port closest to the scene of the stranding.

Upon arrival at the airport/naval air station/Air Force base closest to the harbor of that port, the DSRV is again placed on its trailer (or was transported in the cargo plane on it) and trucked to the port, where it is loaded aboard the submarine. The submarine proceeds at flank speed to the scene of the accident, and, upon arrival, the crew of the DSRV launches off the sub's deck and proceeds to the stranded sub. The crew members enclose the sub's escape hatch with the vehicle's "transfer skirt," lock on, pump out the water and pressurize to one atmosphere, and signal the sub crew. Crew members (twenty-four at a time, it was decided in the course of the design phase) exit the sub and enter the DSRV for transport to the rescue sub hovering nearby. The procedure is duplicated in attaching to the rescue sub's hatch, and the rescued sailors are brought aboard. The DSRV returns for another load of crewmen, until all have been rescued.[11]

NUC roles in DSRV critical

The Naval Undersea Center, which had developed and would continue to design and develop a large number of submersibles throughout the 1970s and

[11] For a fairly realistic and visual portrayal of the process, the interested reader is directed to the 1978 Hollywood movie *Gray Lady Down*. DSRV also appears in the movie *The Hunt for Red October,* but the "magical appearance" of the vehicle is less realistic.

In case of a submarine emergency, the Deep Submergence Rescue Vehicle would be loaded aboard a submarine like the USS *Hawkbill* (SSN-666) and carried to the site to effect a rescue.

beyond (when it became the Naval Ocean Systems Center), played peripheral but critical roles in putting DSRV to sea. For one, transportation logistics are substantially important in any rescue operation, as described in the *Pisces III* event related at the beginning of this chapter and the suggested scenario immediately above. Lockheed, which won the contract to build the DSRVs, also built a trailering device similar to a tractor-trailer flatbed and a Handling Training Vehicle (HTV) during the early system development days. The HTV was a full-size mock-up of DSRV (including the critical components of length, diameter, and weight), which was handed over to NUC personnel with the trailering device to test transportability.[12] They were trucked around the San Diego waterfront area and out and about on San Clemente Island to ensure they worked effectively. The HTV was also hoisted on and off submarines at the submarine base at Ballast Point near NUC headquarters to determine the finer points of handling that critical operation in as short a time as possible while ensuring the safety of the craft.

[12] NURDC *Seascope,* April 4, 1969, 1.

The vehicle

The DSRV itself had a cylindrical hull eight feet in diameter and just short of fifty feet long. The free-flooding outer hull was constructed of fiberglass. An inner pressure hull fabricated of three-quarter-inch thick HY140 steel consisted of three interconnecting spheres, each seven-and-a-half feet in diameter. The forward of those was for the vehicle operators, the middle and aft sphere for the one or two DSRV crewmen and a maximum of twenty-four personnel from the stranded sub.[13] Powered by two twelve-volt silver zinc batteries, with a third for emergencies, propulsion was provided by a reversible fifteen-horsepower DC motor. There were also vertical and horizontal propulsion motors.[14]

The control and navigation equipment, at the insistence of Craven based on the precision maneuverability required, was designed and built by the Massachusetts Institute of Technology Charles Stark Draper Laboratory. His concern was a human pilot, no matter how expert, could not understand the complex and unpredictable fluid motions in the undersea environment, and thus might be unable, at the most critical moments of closure with the submarine hatch, to maneuver the vehicle successfully.[15] He noted the Draper Lab

> would later produce the computer and displays for the Apollo landing system that would guide America's astronauts to their first landing on the moon. As it turned out, a more complex computer system would be needed for the DSRV, since it was much more difficult to control a hovering craft in a fluid medium than in outer space.

The Point Loma undersea center designed the submersible's optics suit. That included underwater lights, still and TV cameras, pan-and-tilt mechanisms, and

[13] In an interesting paragraph (page 118-119), Craven discusses the possibility the "rescuees… physiological and psychological capacities might be impaired, and some might be irrational and wish to take control of the DSRV or interfere with its operations." Based on that, he posited "the pilot and copilot be protected from such irrational behavior," and visualized them (probably both officers) locked up and out of danger in the forward sphere, with the lone DSRV crewman in back (an enlisted sailor) the sole target of the irrational behavior.

[14] Thomas J. LaPuzza, "DSRV-1 launched in ceremonies at San Diego," NURDC *Seascope*, January 30, 1970, 4.

[15] Craven, *The Silent War*, 120.

"viewport optics systems."[16] Ivor Lemaire reported that in order to gather necessary data to build the suit,

> we built a mock-up of wood of the whole underside of the DSRV and suspended it in water and ran all of our optical tests from this big old half a hull … and had all the cameras located and checked different locations to make sure that in the final version they had good vision of the downed submarine.[17]

The viewport optics system was interesting in that the pilot had to look downward at the "floor" to see out the porthole as he was approaching his target. Unfortunately, he couldn't get his head down far enough for that, so Lemaire worked with a periscope design contractor to have a "tube" built that allowed him visual sensing of the downed sub and its escape hatch.

The Center's work site for DSRV was fairly close at hand, as a huge prefabricated building was constructed at the south end of its property adjacent to San Diego Bay to house the DSRV and provide office space for its crew. Center piers were a few hundred yards away, and the submarine base was about half a mile to the south, facilitating quick and easy mating of DSRV with a submarine of opportunity if an underwater emergency occurred in the vicinity of San Diego. Naval Air Station North Island was about a thirty-minute drive if the rescue system required airlifting to some distant port for rendezvous with a submarine there.

Additionally, as described in the DSSP "Fact Sheet" mentioned above, facilities for the project were also constructed at the Center's San Clemente Island facility. That occurred as a result of a fortuitous meeting early on in the formation of the Special Projects Office. Ivor Lemaire, in discussing his boss Howard Talkington's penchant for "volunteering his services to various committees" and attending their meetings to offer Center support, mentioned one of those meetings was the Advanced Sea-Based Deterrence Conference, held at the Naval Post Graduate School in Monterey. There they met for the first time Levering Smith and his chief scientist, Dr. John Craven, who had organized the meeting in Monterey and "basically Polaris was born of that."[18]

As a result of the meeting, they invited Dr. Craven to see one of the key elements of the support they could provide: San Clemente Island. The result, according to Lemaire, was, "…he was smitten by [it]. He thought it was just great,

[16] Naval Undersea Research and Development Center, *Ocean Engineering*, NURDC TP 278, January 1972, 60-61.
[17] Ivor Lemaire interview, 35.
[18] Ivor Lemaire interview, 16.

just exactly what he was looking for, for his testing. So that's how we got our foot in the door."

That initial visit was followed by the extensive testing program on Polaris at San Clemente Island described in Chapter 8; at the time the "Fact Sheet" was published, planning was underway for a similar effort on the new Poseidon missile. Other programs and specialized test facilities were being planned by DSSP staff officers at the island as well. In mid-1970, the undersea center newspaper announced the DSSP building on the island had been completed. Lack of congressional funding for a portion of the effort stimulated Center facilities designers to make last-minute modifications, allowing accelerated use of other MILCON (Military Construction) structures for DSRV maintenance, repair, and storage until complete funding was in hand.[19] Among its several useful features, the DSRV Launch and Repair Facility had a set of railroad tracks running five hundred feet into the water to facilitate vehicle launch.

DSRV crew training

An essential element in the development process as the lead DSRV was put in the water was crew training. The Navy throughout its history has been rigorous in establishing appropriate training venues and curricula for all personnel operating its platforms on and under the sea and in the air. DSRV, however, was an entirely new platform, vaguely resembling a submarine but with none of the same missions and substantially different operating principles. Operating in the "open" sea underwater was relatively straightforward and probably undaunting to the personnel selected for the assignment; it was merely a matter of getting accustomed to the "feel" of the craft and its controls. The critical element, however, was the exacting process of maneuvering the craft into position where it could dock with a fairly small submarine escape hatch, with only a small margin of error. Even with the MIT computer-based navigation system, that would require substantial practice and an appropriate place (obviously an underwater range of some kind) to practice, and a means for the Navy's Operational Test and Evaluation Force personnel to determine the craft and operators were "approved for service use," to borrow their formal certification phrase.

[19] NURDC *Seascope*, May 15, 1970, 1.

As it had for torpedo evaluation for many years and for the very recent test program for Polaris, NUC's San Clemente Island facility provided an excellent test area; all that was required was a means of conducting realistic operator training and vehicle testing: "… in order to certify the submersibles—the Deep Submergence Rescue Vehicles—they were going to need a test fixture. You can't get test time with an operational Fleet submarine," recalled Bob Watts, who at this point in his Navy ocean engineering career had barely completed his Junior Professional tours and was still several years away from managing the CURV program.

He cited the reason for his big opportunity early on:

> …in those days we had a very diverse, you might even say 'divergent,' work force… there was a part of the crowd that was like the Gulf Coast roughnecks, and there was a part of the crowd that was the engineers and the guys with the slide rules hanging from their belts. Somehow I was able to work with both groups successfully.[20]

Encountering "too much friction" on the project and recognizing this quality in Watts, Howard Talkington asked him to take over as project manager for the Simulated Distressed Submarine.

Watts recounted the Center had been tasked by DSSP to design and contract for fabrication of the test fixture and had been fortunate in finding steel "I-beams, H-beams" that had been formed into circular sections for the Moho Platform.[21] The Mohole Project was based on a proposal to retrieve samples of the earth's mantle by drilling through the crust to the Mohorovicic discontinuity, under the theory such samples would contribute substantial data on the age, make-up, and internal processes of the earth. Since such drilling was impractical from land, an informal group titled the American Miscellaneous Society initiated a three-phase program with the drilling of five holes in the Pacific seafloor off Guadalupe, Mexico, in the spring of 1961. After the "unprecedented success" of phase one, a failed relationship with a government foundation and congressional withdrawal of funding terminated the program in 1966.

In his interview, Watts stated the I-beams and H-beams had been bent for use on a planned semi-submersible drilling platform for the project. When it was determined the drilling could be accomplished at less cost using a drill ship (the

---

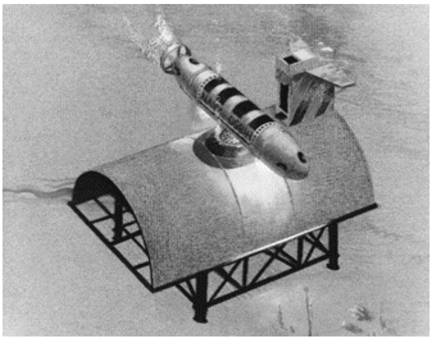
[20] Bob Watts oral history interview II, conducted by Tom LaPuzza, September 20, 2012, 11.

[21] "Mohole Project," National Academy of Sciences, 2005, http://www.nationalacademies.org/history/mohole/ visited May 17, 2019.

Glomar Challenger was the ship), the beams became surplus materials that were then acquired for use on the Simulated Distressed Submarine fixture:

> These just happened to be on a seventeen-and-a-half-foot radius, for a thirty-five-foot-diameter hull. Well, that's perfect to simulate the hull of a submarine. So we took those, built an undercarriage that had hydraulic legs on it so that it could sit on an uneven bottom and level itself. And then the C-frames were used to simulate the top of the submarine hull.[22]

The center section of the fixture was designed to be rotated with hydraulic cylinders so the platform could simulate a submarine on the bottom that was still in trim or one that had listed as far as forty-five degrees to port. On top of that section was a landing pad and escape hatch identical to those on submarines. Although "its primary purpose is to assist in the evaluation of the capabilities of the DSRV," it would "also be used for pilot familiarization and training."[23] Watts was assigned to manage completion of the test fixture fabrication.



Artist's concept demonstrating the Simulated Distressed Submarine on the seafloor, with DSRV practicing mating procedures as would be done in a submarine emergency.

Watts' involvement included initial evaluation of the fixture in Long Beach and transport to and installation two hundred feet underwater at San Clemente Island. He also recalled a more challenging effort, fabrication and installation of the "Deep Seat": "DSRVs also needed to prove that they could land and make a seal on a plate that would simulate a submarine at full test depth. So we built, again, a big landing pad and the hatch and all of that structure, but no rescue chamber underneath it, just a closure underneath it." Positioned on the sea floor at a depth of fourteen hundred feet, it allowed the vehicle to "land on the pad, simulate transferring personnel into the DSRV, close it, re-water the skirt, and take off…"[24]

Over the next several years, Center personnel assisted in the various testing

---

[22] Bob Watts interview II, 13.
[23] NURDC *Seascope*, May 28, 1971, 3.
[24] Bob Watts interview II, 16.

phases of the submersible using the underwater fixtures, making modifications as required, and supporting Submarine Development Group One when the test fixtures were turned over to them. (One significant change was removal of the rotating drum center section in 1975 and replacement by a fixed section with two simulated submarine hatches for DSRV mating welded on at zero- and thirty-six-degree list angles.) The Center's support was duly noted by Oceanographer of the Navy Rear Admiral J. Edward Snyder, Jr., guest speaker at the July 1972 ceremony at the Submarine Support Facility, Ballast Point, marking the acceptance by the Navy of DSRV-2. He commended the vehicle crew and the personnel of Submarine Development Group One, adding, "Their hard labors have been fully supported by the Naval Undersea Center, and by the constant faith and support of believers like Dr. Bill McLean who have fostered the Deep Submergence concept from conception to near reality."[25]

For nearly four decades, the two commissioned DSRVs provided the potential for submarine rescue around the world, an unprecedented technical achievement. Bob Watts, who got the opportunity to dive on the Deep Seat in DSRV, said, "The DSRVs were probably the most sophisticated manned submersibles on the planet at the time they were built."[26] In late 2008, *Mystic* (DSRV-1) was deactivated; *Avalon* (DSRV-2), which had been put out of service eight years earlier, went to a California museum for public display. The undersea craft were replaced by the Submarine Rescue Diving and Recompression System.[27] The cited article stated 155 people could enter a rescue pod and be rushed to the surface, but then contradicted itself and said the people could be rescued sixteen at a time. The official U.S. Navy source confirmed the sixteen at a time.[28]

CURV III to the rescue?

One important and related matter is that shortly after his management of the

---

[25] NUC *Seascope*, August 4, 1972, 4.
[26] Bob Watts interview II, 14.
[27] Robert Johnson, "This Underwater Drone Can Dive 2,000 Feet And Rescue 155 People at Once," *Business Insider*, October 13, 2012, https://www.businessinsider.com/the-srdrs-submarines-rescue-drone-2012-10 visited May 18, 2019.
[28] The U.S. Navy Fact File, "Submarine Rescue and Diving Recompression System," visited May 18, 2019.

SDS completion and operations initiation, Bob Watts was assigned as CURV III program manager. The CURV vehicles will be discussed shortly, but among a variety of responsibilities, the CURV III team supported potential rescue of stranded subs before the DSRVs were certified operational. In the early 1970s, the Navy began construction of a new, large class of nuclear submarines, eventually totaling sixty-two boats, lead of which was USS *Los Angeles* (SSN-688). Whether thoughts of the *Thresher* and *Scorpion* disasters[29] were considered (not unreasonable given they had occurred in the very recent past), the completion and commissioning of the lead boat of the class was pushed back several years, to November 1976. If the boat had gone to sea when originally planned, DSRV-1 would not have been operational for several more years, and that represented a worry. That concern was allayed by a developed procedure and constructed system enabling CURV III to carry McCann Chamber attachment lines to a *Los Angeles* class boat should any become stranded underwater.[30] None was.

CURV: The beginning of the story

Interestingly, CURV was not a product of (or even associated with) either the Deep Submergence Systems Project or the Deep Ocean Technology effort. The Pasadena Annex of NOTS, as has been reported, had developed a number of anti-submarine warfare torpedoes, testing them at sea ranges near Long Beach and off San Clemente Island. The general test principle was the torpedo, once it had performed its required target search, would run out of fuel and, positively buoyant, remain on the surface for easy recovery by one of the annex's torpedo recovery boats. Unfortunately, the anticipated positive buoyancy was not assured and on occasion the torpedoes sank, sometimes to depths beyond the capabilities of human divers. To counter that, Pasadena had developed a recovery system involving a barge and various grappling devices that generally required several days to recover a torpedo.

At the same time, NOTS Pasadena had acquired a contractor's experimental underwater vehicle that was not functional but showed possibilities. Lab personnel

[29] The 1963 loss of USS *Thresher* (SSN-593) was recounted in some detail in Chapters 8 and 9. USS *Scorpion* (SSN-589) was lost in the Atlantic under still unknown circumstances in May 1968.
[30] Bob Watts interview II, 16.

replaced almost everything on the vehicle (TV cameras, thrusters, sonars) and christened it the Cable-controlled Underwater Recovery Vehicle (CURV). Larry Brady, who initially as a contractor and later as a civil service employee would figure prominently in CURV's many international headlines, explained:

> And so we got the thing operational and I became the operator, by sheer force of will. I said I wanted to operate it… So we went out to San Clemente Island… and recovered our first torpedo in about 500 feet of water. And I mean it was 'put the vehicle in the water, drive it to the bottom, acquire the pinger on the sonar, start closing and then acquire the active sonar target, close up to it, put the claw on it, bring it to the surface.' That was the beginning. We then went on to recover four torpedoes in one day. So we essentially put the other group and their barge out of business.[31]

Typical of Center efforts, even low-key test range support efforts, creative engineers and technicians immediately sought to improve the vehicle. Thus, there was a CURV II, and a CURV II-½, and a CURV III. (There were also several different vehicles with the same numbers, e.g., CURV II A, B, and C.)

Before all that occurred, however, the contractor vehicle made to function for the pedestrian purpose of recovering exercise torpedoes on the test ranges was about to become an international celebrity.

Palomares

At 10:20 on the morning of January 16, 1966, an Air Force B-52G bomber designated *Tea 16* slid into place behind *Troubadour 14*, a KC-135A refueling craft. At 31,000 feet over Palomares, a village on the southern coast of Spain, they lined up for a routine mid-air refueling. Moments later, crews performing a similar maneuver a few miles away reported fireballs and spotted a center wing section falling in a flat spin from the sky. *Tea 16* and *Troubadour 14* had somehow collided. All four tanker crew members and three of the seven bomber crew perished; the others parachuted to safety. The incident was rare but not unheard of, and might not have made international headlines but for the fact the lost B-52 was carrying four hydrogen bombs.[32]

---

[31] Larry Brady interview with Tom LaPuzza December 27, 2011.
[32] This and following paragraph: Commander W. M. Place, Colonel F. C. Cobb, Lieutenant

Witnesses described seeing bombs descending under parachutes. Three were located within two days near Palomares, damaged and having released some radioactive material, but not posing a nuclear threat. It was soon evident, however, that the fourth weapon had landed in the Mediterranean Sea.

Unlike the *Trieste* dives in search of the wreckage of USS *Thresher* detailed in an earlier chapter, an underwater trip to locate and photograph the lost object was not the challenge. A means had to be found for retrieving the thermonuclear bomb from the sea floor before someone else, most notably the Soviet Union, located and secured it for study and technology exploitation. The Navy dispatched large numbers of ships and personnel to the area, with a much smaller number of pieces of specialized equipment which might (or might not) be helpful in recovering the bomb. (At some future time, with the planning for the Deep Submergence Systems Project described above, one could speculate the Navy would have had a well-indexed volume of rescue/recovery scenarios, cross-referenced to lists of equipment and personnel required for each of those scenarios. That time was not early 1966.)

First order of business, of course, was finding that bomb. On March 15, the Navy's deep-submergence vehicle *Alvin* (DSV-2) located it, with parachute attached, in 2,500 feet of water, perched precariously on a steep slope. *Alvin*'s operators were able to attach recovery lines, twice, but both times the cables snapped when the lift began. The second time the bomb rolled down the slope to rest at a depth of about 2,850 feet, obviously compounding an already difficult if not impossible problem.

At this point, an unlikely Navy asset was requested. The realization the Naval Ordnance Test Station facility in Pasadena had an operational undersea vehicle, the purpose of which was recovery of items from the seafloor, prompted an urgent effort to bring it to Spain for such a project. With hundreds of torpedoes recovered, CURV was a natural for the operation, with one fairly serious obstacle: the vehicle's control cable was 2,000 feet long, and the bomb was now at a depth of

---

Colonel C. G. Defferding, "Palomares Summary Report," Field Command, Defense Nuclear Agency, Technology and Analysis Directorate, Kirtland Air Force Base, New Mexico, January 15, 1975.

El Alcázar

ULTIMOS DIAS DEL CONCURSO

III Concurso de EL ALCAZAR
Europa en sus manos
CUPON

¡HE AQUI LA BOMBA!

Un documento histórico

Así fue recuperado el artefacto de Palomares

Hoy entra en vigor la NUEVA LEY DE PRENSA

Todas las fotos
Reportaje de nuestros enviados

The NOTS CURV team assembled for a photo after the recovery, including Howard Talkington and Bud Kunz (second and fifth from left), who received the Navy Superior Civilian Service Award for their leadership, and Larry Brady (back, leaning against vehicle), who operated CURV. A Madrid newspaper proclaimed the recovery, including a photo of the bomb and its parachute.

almost 3,000 feet. In short order ("I want to say a day"), Larry Brady and his long-time associate George Stephenson spliced the 55-connector main cable of CURV to an additional 1,000 feet of cable, and Navy aircraft rushed the vehicle, the spliced cable, the control van, and the operating team to Spain.

Operating from one of the recovery task force ships, USS *Petrel* (ASR-14), Brady maneuvered the vehicle to the sea floor and attached a specially designed grapnel hook to the bomb. Confident the attached line would allow safe recovery of the weapon, he nevertheless responded appropriately to the orders of the Navy admiral in charge and dove the vehicle twice more to attach additional recovery lines, the third time entangling the vehicle with the bomb's parachute and rigging. *Petrel*'s crew hauled in the two main recovery lines and brought bomb, parachute, CURV, etc. aboard the submarine rescue ship. International headlines followed.

Back to reality

In spite of those headlines, with "*La Bomba*" (as it was cited in area Spanish newspapers) secured, the CURV team went home to San Diego and back to the test ranges and the day-to-day of torpedo recovery. The success of the vehicle, however, and the clear message that it was the unique Navy asset for the recovery, suggested several things: improving the original vehicle, increasing its depth capability, and constructing more such vehicles.

In succeeding decades, a whole series of CURV vehicles would be developed and put to sea, normally for the fairly mundane test range recovery task. One would be built for the Naval Torpedo Station at Keyport, Washington, where similar torpedo testing was done, and a number of them sank in waters too deep for divers or the outmoded recovery system they had. Over the course of several years and more than several design iterations, the most critical improvement was increasing operational depth capability, from the several-thousand-foot range of CURV I to seven thousand, and later to ten thousand feet. Electronics were upgraded, as were the underwater lights and cameras.

In terms of the vehicle's human partners, Larry Brady would retain his position as primary vehicle operator, transitioning from contractor to civil service employee. However, Howard R. Talkington, who as the NOTS lead for the Palomares recovery had earned a Navy Superior Civilian Service Award, determined he wanted a new program manager. As related in the Simulated Distressed Submarine coverage earlier, Bob Watts had been called upon to exercise his ability to work with a wide variety of people in managing the final stages of fabrication and deployment of SDS. With that assignment successfully completed, Talkington named him manager for the CURV III program in early

1970.[33] At the time, the team was operating a brand-new model of the underwater vehicle, which had been tested only once to 6,000-foot depths. It would, nevertheless, operate successfully in a real-world situation at that depth almost immediately.

More heroics

In March 1970, the National Aeronautics and Space Administration (NASA) launched a rocket with a sophisticated instrument package to record photographic and other data of a solar eclipse. The package, with the photos and data aboard, landed in the Atlantic Ocean about seventy-five miles east of Norfolk, Virginia, and sank to the bottom 5,850 feet below.[34] After several days of consideration, the Navy's Supervisor of Salvage requested the assistance of CURV III in recovering the package and the irreplaceable data it contained. Two lengthy (fourteen and sixteen hours) dives failed to locate the package. Finally, on March 21, working all night in rough seas, the CURV team found the unit and secured it for the nearly nine-hour ascent and recovery by the support vessel, USS Opportune (ASR-41). The package was turned over to NASA officials, and CURV and crew returned to Long Beach.

They returned as well to their primary task of developing a vehicle to work the Navy's new, deeper test ranges, notably the Atlantic Underwater Test and Evaluation Center (AUTEC): "We were trying to make a system that could go to 7,000 feet and survive and have something left over to do some useful work," Watts said in a 2011 interview.[35] "The task was more integration of commercially available systems than technology development." Among significant changes was the replacement of the hollow aluminum cylinders that had characterized earlier CURV models with what at the time was brand-new syntactic foam, square blocks of which provided the needed positive buoyancy. The team moved the hydraulics out of the electronic component housing because they did not require pressure compensation. And the electronics, as operating depths increased to 10,000 feet, were housed in 7075-T6 aluminum cylinders--aircraft aluminum.

[33] Bob Watts email to Tom LaPuzza, May 20, 2019.
[34] NURDC *Seascope*, March 27, 1970, 1.
[35] Bob Watts oral history interview I, conducted by Tom LaPuzza December 20, 2011, 6.

"One of the most remarkable technology developments of the CURV program was the oil-filled, pressure-balanced cabling," Watts commented. "If I understand it all correctly, that was Bob Pace's idea.[36] The main connector for CURV was a 55-pin connector…" because there was no multiplexing.

Over time, the cable aged, and not always gracefully, but the more modern cables were also much more expensive: "We struggled with the existing cable all through the program because of the costs of using newer tech[nology]. However, we did use some control conductors to implement some multiplexing which gave us additional control functions."[37]

The control cable, obviously essential, nevertheless represented one of the challenges of underwater operations. It was long, and heavy, and bulky, and sometimes got in the way or became entangled in underwater debris. When that occurred, often unknown to the operator whose only vision was what his closed-circuit TV cameras could "see," an unfortunate result could be the severing of the cable. For that reason, Watts said, "The cardinal rule with unmanned vehicles is always go down positively buoyant. Use your power and thrust to get down."[38] If power was lost for some reason, such as severing the control cable, the vehicle would float to the surface and could be recovered.

The value of powering the vehicle down with positive buoyancy was demonstrated while Watts was working the Center's ocean engineering demonstration at San Clemente Island in September 1971 (described below). Primary operator Larry Brady was with the team several hundred miles to the southwest at San Juan Seamount, a 12,000-foot-high mountain whose summit was nearly 2,000 feet under the surface. The undersea center had installed an underwater range called the Inter-Seamount Acoustic Range between San Juan and Westfall Seamount, two hundred miles away, to study underwater acoustics. The transmitter on San Juan was powered by a radioisotope thermoelectric generator that had to be recovered following shutdown of the range. During the September 1971 attempt, underwater debris sliced through CURV III's control cable. With its positive buoyancy, it surfaced fourteen hours later, at the precise

[36] Pace was a mechanical engineering technician involved in day-to-day recovery operations at San Clemente Island as CURV II primary operator. More notably he had been a member of the original CURV team that recovered the hydrogen bomb in the Mediterranean. In his later career he transferred to Hawaii and was a principal in work on the Stable Semi-submerged Platform, including serving as craftmaster.

[37] Bob Watts email to Tom LaPuzza, May 20, 2019.

[38] Bob Watts oral history interview I, 10.

spot the team had calculated it would be. (Eventually, after four attempts, the generator also was recovered.)[39]

Equally challenging was an assignment to the NATO Azores Fixed Acoustic Range, where a 120-foot-high tower weighing seventy-two tons in water had to be recovered from the seafloor. The CURV crew was tasked with connecting a recovery line to a bale on top of the tower by attaching a shackle over the bale. The CURV vehicle, operated by Brady, connected to the shackle "with a three-inch power braid line that was stored on the vehicle in an upside-down garbage can with masking tape to hold it in place," said Watts, with a chuckle at the interviewer's remark about "high tech."[40] At the other end of the power braid was a thirty-five-ton snap hook, which CURV passed to the French ship *Tarabelle*. The vessel had a hydraulic motion-compensation system with a heavy-lift capability, and pulled the tower up from the depths.

The story of the life-saving *Pisces III* rescue initiated this chapter, but there was a final noteworthy CURV exploit: in 1976, CURV III was requested to provide underwater footage of the wreck of the SS *Edmund Fitzgerald*, a Great Lakes iron-ore carrier that sank during a violent storm on Lake Superior in November 1975. Immortalized in the Gordon Lightfoot song "The Wreck of the Edmund Fitzgerald," a television production featured CURV III conducting the inspection with Lightfoot's song twanging in the background.

Over the years following the H-bomb recovery, the Navy's Supervisor of Salvage (SUPSAL) funded most of the CURV work outside of the test range torpedo recoveries. When the Base Closure and Realignment Commission action of 1991 put the Center out of the torpedo business (and thus out of the torpedo recovery business), members of the CURV team continued to provide essential input to the SUPSAL staff as it designed and built its workhorse CURV 21 to serve as the Navy's premier recovery system in the future.

Bob Watts

A large number of Center employees might be said to have "grown up" with

---

[39] "CURV III And FLORIKAN Recover Nuclear Generator," NUC *Seascope*, May 7, 1976, 1.

[40] Bob Watts interview I, 15.

the lab, but that had almost a literal meaning for Bob Watts "because I lived in Pasadena all the time I was going to school from second grade on and actually had a neighbor who worked at the lab during my high school years."[41] A Christmas food drive at the Pasadena lab benefitting local families in need made a substantial impression on him; as a junior high student he got to go along "just as a helper." When he had finished his undergraduate studies and was looking for career employment, the lab appealed to him for a different reason that only took final form after he'd worked awhile: "…in private industry you get to see a piece of the elephant. At the lab, if you're ambitious and aggressive, pretty soon you get to design the whole elephant, and train it to do tricks."

After management of the Simulated Distressed Submarine and CURV III (which was transferred to the Supervisor of Salvage in 1986), he designed a potential replacement for Scripps Institution of Oceanography's Floating Instrument Platform to support Center surveillance programs. He also contributed to a concept effort to deploy underwater volumetric arrays of hydrophones.

In his later career, he supported test and evaluation of a Navy plan to convert some of its ballistic missile submarines, limited in number by the Strategic Arms Limitations Treaty (SALT) agreements, to guided missile submarines.

Two of his most important contributions were less technology and more training. He managed the New Professional program for half a dozen years, characterizing it as "vastly successful." And despite never attending one himself, he developed a program managers' training course, admitting imparting the required knowledge was a "monumental" task to perform in a training period of forty hours. He succeeded by making attendees "aware of what all of those parts and pieces are [of program management], and what they entail, and how deep they need to go in those areas, so that if they're lacking in some area, they have a resource…to fix that."[42]

He later assisted the Navy Office of Personnel Management effort to ensure high-quality federal personnel in technical fields, through the OPM advisory Professional Council of Federal Scientists and Engineers. After Watts served on the steering committee for several years, he chaired it for fourteen more, until his retirement in 2006. Shortly thereafter he was presented the council's first annual William Randolph Riley Award for his exceptional leadership (an award named,

[41] Bob Watts interview I, 1.
[42] Bob Watts interview II, 30-31.

incidentally, for the Center's Demonstration Project developer and personnel officer Randy Riley, who will be discussed in Volume II).[43]

Decades of submersible development

The early development of the CURV vehicles initiated

> the many-decades history of underwater vehicle development and involvement at what is today [NIWC] Pacific. That history comprises ten manned vehicles including a bathyscaph and a Navy submarine, nearly two dozen unmanned vehicles, and ancillary craft, platforms, and structures, all directed toward two important missions: to provide the Navy underwater work capabilities, from shallow water down to extreme ocean depths, and to allow humans the opportunity to view the underwater environment in an 'up-close-and-personal' manner.[44]

Ivor Lemaire, who later would head the Center's Ocean Engineering Division, authored a technical document which summarized the division's underwater vehicle development efforts. Describing the origins of those developments, he wrote,

> During the early 1960s, NOTS engineers developed the Navy's first ROV, CURV, which, by 1965, could retrieve sunken ordnance from depths of 800 feet. CURV, a surface-powered, cable-controlled, underwater system that integrated TV, sonar, still cameras, and a variety of manipulators and grabbers, successfully validated the concept of an underwater work system.[45]

The ocean engineering organization which he would head produced a substantial number of formal and informal documents similar to the one just cited—technical documents and technical publications, as well as a variety of brochures—which he or his mentor Howard Talkington wrote or sponsored. That was done for a reason:

> [Howard Talkington] was big on information flow. He said, 'Ivor, the people in Washington—the managers in Washington—thrive on information. That's all they've got. They can't go out to a lab and tinker. All they can do is plan. When you walk into someone's office and you can leave them with a juicy tidbit of information … see, that's the way to do it.'[46]

---

[43] Space and Naval Warfare Systems Center San Diego *Outlook*, December 15, 2006, 2.
[44] Tom LaPuzza, "SSC Pacific: Underwater Vehicle Development," *Mains'l Haul*, Vol. 48: 3 & 4, Summer/Fall 2012, 46.
[45] Ivor Lemaire, "NOSC and Remotely Operated Vehicles (ROVs) and Autonomous Unmanned Vehicles (AUVs)," NOSC TD 1448, November 1988, 1.
[46] Ivor Lemaire interview, 8.

An official Navy publication with solid facts on depth capability and a listing of underwater missions certainly worked in that environment.

As was obvious from Lemaire's 1988 document and others like it, the Center, under its various names, pursued a wide variety of underwater vehicle development, ranging from a fifty-pound submersible that was little more than a maneuverable underwater camera to a five-and-a-half-ton CURV-like behemoth with highly articulated manipulators and an array of tools it could use to make extensive repairs at depth, and at an impressive depth, like 20,000 feet.

Manned vehicles

What most intrigued people, however, first and foremost of whom was William B. McLean himself, were the manned vehicles. The Point Loma lab and its various predecessors have always had scientists and engineers well trained in-house to work comfortably and effectively as divers in the undersea environment. That is a strange and somewhat forbidding environment, however, for most people, breathing life-essential air through an uncomfortable mouthpiece and viewing an often-murky liquid scene through fifteen square inches of plastic that tended to fog up, rendering one mostly blind. Snorkeling, perhaps, is a reasonable compromise, with the surface only a head-raising away if salt water gets into the mouthpiece or the plastic fogs up. On the other hand, that allows only the barest glimpse of an environment that is often at least as fascinating as it is forbidding.

McLean, a "skin-diver" much of his life, invented wet suits and breathing equipment so he and his family could venture underwater. With his own delight in these adventures, he imagined the possibility of opening up that fascinating undersea world with personal pleasure craft that could cruise comfortably several hundred feet underwater. Their transparent hulls would provide breathtaking panoramic views of richly colored sea life to those inside, passengers breathing comfortably at one atmosphere, wearing hiking shorts, golf shirts, and sandals, and snapping photos for the folks back home. He visualized pilots of private single-engine planes and skippers of cabin cruisers, then transferred that visualization under the ocean's surface.

He also envisioned this concept as a means of jump-starting Navy programs in this area: "It seems to me that the primary commercial hope for undersea exploration lies in the recreational area. This is the only source of funds of sufficient magnitude to really get undersea operations going."[47] Citing Jacques Cousteau's popularizing of skin diving, which resulted in tremendous growth in that area of recreational interest, he continued,

> I believe the submersible field can see the same explosion—if a vehicle can be designed that will fit within the budget of the individual sportsman and that will allow him to extend his operations from 50 or 60 ft [sic], which most skin divers achieve, down to 400 or 500 ft…

The large number of pleasure boats at docks around the country indicated the "tremendous reservoir of funding available for exploring something new."

On the other hand, later in the interview McLean expressed concern about barriers to his imagined substantial growth in undersea vehicle use by the general public—the

> regulatory area… I can see the government establishing regulations… which will prevent the construction of anything that has widespread application, and establishing requirements for design of civil[ian] vehicles that can't be met simply… If the FAA regulations had been in effect at the time of the Wright Brothers' first flight, we never would have gotten any aviation going.

Typically, McLean did more than merely philosophize: as the Naval Ordnance Test Station technical director, he invested Navy funds in the development of undersea technology and as a private citizen he invested his own. The latter came in the form of $10,000 accompanying his receipt of the Rockefeller Public Service Award for Science, Technology, and Engineering in 1965.[48] The article announcing the award reported he would use the funds "to explore his personal interest and ideas in undersea technology," citing his belief that "exploration of the ocean is of great national importance for both political and economic reasons." It is interesting, and perhaps intentional, the other front-page article in that issue reported McLean's addressing a press conference at the Pasadena facility, revealing for the first time the NOTS work on *Moray* and *Deep Jeep*.

As noted in Chapter 10, those vehicles had been under development at China Lake for several years. *Moray* was a two-man submersible, designed for depths of 6,000 feet. Its external free-flooding hull fashioned of ring-stiffened fiberglass and syntactic foam rendered it positively buoyant. McLean envisioned it as a "two-

---

[47] William B. McLean, "A Bedrock View of Ocean Engineering," *Astronautics and Aeronautics*, April 1969, 32.
[48] Naval Ordnance Test Station *Rocketeer*, November 12, 1965, 1.

man torpedo," to be "flown" in the same fashion as a fighter plane, carrying anti-submarine weapons. Norm Estabrook, in a 2011 interview, also mentioned duty as a protective "escort" for a ballistic missile submarine.[49] Given the security considerations, McLean described it at the press conference as an "undersea laboratory." Although substantial progress was made in its development, the revolutionary design was also its downfall: the Navy, in developing its fighter planes for the sky, had a substantial infrastructure for aircraft development, repair, and maintenance and for aircraft pilot recruiting and training. The cost of a similar infrastructure for undersea "fighter" craft would be prohibitive.

After testing in a China Lake reservoir, *Moray* was launched at San Clemente Island, where it made about twenty-five manned dives to maximum depths of 250 feet, reaching underwater speeds up to twenty knots. "Once the feasibility of the concept had been proven and demonstrated," according to long-time undersea technologist Will Forman, "the project was discontinued."[50] Subsequently, the vehicle was transported to the Hawaii Lab when it was established, but *Moray* was never operated again.

Deep Jeep consisted of a five-foot-diameter steel sphere, powered by outboard motors and "flown" underwater much like a helicopter. It was launched on January 21, 1964, from a pier near Santa Barbara, with designer Will Forman as the pilot.[51] By virtue of its launch, it became the first American-made deep submersible. Forman and copilots made a series of dives around San Clemente Island, and in 1965 descended to 2,010 feet, at the time a record for an American-made submersible.[52] Early in its development, Forman traveled to San Diego and met with Lieutenant Don Walsh and others of the *Trieste* crew at the Navy Electronics Laboratory, from which he gained valuable insight about such things as placement of underwater lights. Some years later, Walsh would write the introduction to Forman's authoritative submersible history.

When the Navy completed its assessment of *Deep Jeep* and saw no additional requirements for it, it was loaned indefinitely to Scripps Institution of

---

[49] Norm Estabrook China Lake interview conducted by Leroy Doig III and Mark Pahuta, 9 August 2011, 18.

[50] Will Forman, *The History of American Deep Submersible Operations, 1775*-1995 (Flagstaff: Best Publishing Co., 1999), 262.

[51] Cliff Lawson, *History of the Navy at China Lake, Volume 4, The Station Comes of Age* (China Lake, California: United States Navy, Naval Air Warfare Center Weapons Division, 2017), 490.

[52] *The Station Comes of Age*, 491.

Oceanography, which employed it "to observe marine life and collect data off the Continental Shelf and submarine canyon west of La Jolla."[53]

Dual projects

Both submersibles unveiled at the Pasadena press conference had proposed operational tasking, although, as previously stated, the classified portions of that were not revealed. The next efforts, funded by the Rockefeller award money and NOTS discretionary funds, were more in line with McLean's notion of personal and commercial exploitation of the undersea environment. McLean began

> modeling, off duty, design concepts for submersibles intended for small commercial organizations, institutions, and private owners. He hopes to get the cost per unit below $10,000. He is now on his fifth or sixth version, which until recently have been catamarans. Experiments in controlling externally located propulsion systems by radio and light signals have been conducted.[54]

Simultaneous with McLean's private development, and sharing the same NOTS swimming pool as its testing venue, was the effort headed by Don Moore (and sponsored by McLean's discretionary funding) to develop a similar submersible. Like McLean's personal effort, this was fashioned as a catamaran vessel with a transparent sphere that was nestled between the hulls. It evolved from an earlier effort at China Lake, based on a concept suggested by Tom Lang sometime in between his extensive hydrodynamics research and his pioneering work with marine mammals. Will Forman characterized Lang's concept as the first reasonable proposal for an acrylic-hulled deep submersible. The Utility Submarine featured a transparent sphere for a pilot and observer. Its very basic design was enhanced with Don Moore's development of a similar manned submersible:

> *Hikino* was an extension of the work done in the Utility Submarine project. Officially, the purpose of the *Hikino* prototype was 'to furnish information and incentive to develop a submersible to fill

[53] Naval Ordnance Test Station *Rocketeer*, June 10, 1966.

[54] W.B. Forman, "Submersibles with Transparent Structural Hulls," *Astronautics and Aeronautics*, April 1969, 39. Forman, one of the pioneers of manned undersea vehicles, was the project manager of *Deep Jeep* and went on to develop the *Deep View* manned submersible. He and McLean shared a common vision of a large, transparent pressure hull for maximum underwater visibility.

an existing need for an inexpensive, unlimited depth, high visibility, safe, self-sufficient vehicle for research and military applications that individuals from governmental agencies as well as college professors could afford to operate.'[55]

Based on McLean's belief in the utility of employing glass for a pressure hull, due to increased compressive strength with depth increase, a contract had been awarded to Corning Glass in New York state to construct a five-foot-diameter, inch-and-a-half-thick glass sphere. While awaiting arrival of Corning's deliverable, acrylic plastic was used for the "mock-up" of *Hikino*. (Corning's glass sphere was delivered in mid-1966.)

A *Rocketeer* of the period ran a front-page story on the craft, without the name, showing McLean, in bathing suit and glasses and holding a movie camera at the ready, prepared to dive in the deep end of the NOTS swimming pool. Diving with him was a Junior Professional mechanical engineer named Ron Cohn. The article is somewhat confusing in that its title in about 72-point type screams "Glass Sphere," and it addresses the use of glass underwater. The photo cutline states, "The glass has been tested at over 7,000 feet," but the first sentence of that cutline says McLean and Cohn are, "In plastic version of glass cockpit."[56] As will be discussed immediately below, the plastic versus glass was an interesting trade-off for manned vehicles.

Hikino's design featured two identical transparent hemispheres (of either glass or plastic, with the latter only a quarter-inch thick, but intended for depths less than twenty feet), joined together with a hinge at the back that allowed the two to open and close not unlike a clam shell. When closed, the two occupants sat on chairs, surrounded by an unlimited view from a fifty-six-inch-diameter transparent sphere. It was emphasized only the occupants, the chairs, the critical air-filtration system, and a controlling device were in the sphere, and there were no hull penetrations that might cause water leakage or fracturing of the glass/plastic: "McLean proposed an ingenious system by which control signals generated inside the sphere would be transmitted through the transparent sphere material to photelectric-cell receivers in the hull."[57]

The sphere was supported by two marine plywood hulls coated with painted fiberglass. The vehicle measured sixteen feet in length, was eight feet wide and

---

[55] *The Station Comes of Age*, 506, which in a footnote states "The term 'Hiki No' is an interjection in the Hawaiian language meaning 'it can be done' or 'can do.'"
[56] NOTS *Rocketeer*, June 24 1966, 1.
[57] *The Station Comes of Age*, 507.

five-and-a-half feet high, and weighed 5,700 pounds in air. The 1,750 pounds of ballast in the twin hulls made it neutrally buoyant.

An equally innovative aspect of *Hikino* was its propulsion system, consisting of a pair of cycloidal propellers, or thrusters. This technology dated back in some related fashion to German World War II minesweepers and had been employed on a quarter-scale model submersible in 1965 by NOTS hydrodynamicist Leonard Seeley, who had studied under its German inventor at the University of Washington.[58] Parallel blades like wings extending from a rotating disk allowed, based on the pitch of the blades, forward and reverse motion and effortless change of depth and direction. In essence, a vehicle so propelled could "fly" through the water like a helicopter without the usual combination of separate vertical and horizontal thrusters characterizing most undersea vehicles in their movements.

For *Hikino* propulsion, NOTS inventor Elmer Slates fashioned a cycloidal propeller system belt-driven by DC motors and powered by lead-acid batteries, for which he would receive a patent. A contractor was awarded $15,000 in June 1966 to fabricate the submersible, which was delivered in December.

Testing began in January 1967, with initial trials in the Supersonic Naval Ordnance Research Track (SNORT) braking reservoir, where zero visibility severely limited gathering any meaningful data, followed by additional brief testing at Morris Dam. Later the craft was towed to Shaver Lake near Fresno, California, where it made several dozen test dives. According to the test report, the operator "became hot" when the vehicle was resting on the lake surface. Blocks of ice and cooling fans were added to handle this problem.

The submersible was featured in a 1966 issue of *Popular Science* magazine, with photos of McLean inside. More significant than those photos were the illustrations depicting his dream, a gentleman and lady of leisure in beach attire, cruising underwater in their pleasure craft. An early issue of the Naval Undersea Warfare Center's *Seascope* (April 12, 1968) included photos of NBC National News reporter Frank McGee chatting with McLean and inside the sphere preparing for a pier-side dive.

[58] *Station*, 501.

Makakai

That *Seascope* story was one of several dozen that appeared in the newspaper issues of the 1960s-1970s, reporting on the latest undersea vehicle emerging from the creative minds of Center ocean engineers. As noted relative to CURV, they often represented evolutions: the Utility Submarine improved became *Hikino*, and it evolved into one of the early Hawaii Lab creations, *Makakai.*

Doug Murphy, one of the first recruits from the Naval Ordnance Test Station/Naval Weapons Center to transfer to the new undersea center Hawaii Lab in the late 1960s, had worked on *Hikino* development while still at China Lake, particularly the glass hemispheres. He found it difficult: "The challenge with using glass as a structural material is that it is the ultimate brittle material. It has great compressive strength, but is very weak in tension, which is a challenge when mating hemispheres or putting pass-throughs in the hull."[59]

While still working at China Lake, he built a hull using the Corning Glass hemispheres and tested it in the pressure chamber at the Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, but "it was obvious that getting glass certified for a manned hull was going to be a long-term project." When Murphy transferred to Hawaii, Don Moore appointed him head of the Submersible Systems Branch, and he began work on a new underwater vehicle along the lines of *Hikino*, originally called the Transparent Hull Submersible. He said it "was developed to take the glass hull when available using all the technologies that glass would require, like penetration-less communication through the hull for control, and pressure-compensated batteries and electronics."[60]

In order to continue progress while the glass issue was being worked, an acrylic plastic sphere was purchased from NCEL. Port Hueneme materials engineer Dr. Jerry Stachiw, who transferred to the undersea center in San Diego about this time frame, had developed the sphere technology for use on NCEL's Naval Experimental Manned Observatory (NEMO), which will be discussed shortly. With the acrylic sphere secured, Murphy designed a vehicle eighteen-and-a-half-feet long, with a width of eight feet. The two pontoons of the catamaran-shaped vehicle were connected by a rectangular structure fashioned of aluminum tubing. Four radially oriented pads supported the air weight of the

[59] Doug Murphy email to Tom LaPuzza, May 26, 2019.
[60] Murphy email.

pressure hull sphere.[61] The pontoons contained variable ballast tanks at each end for control of buoyancy, trim, and pitch while underwater, and twenty golf-cart batteries in cylindrical pods provided propulsive power. Three additional batteries provided power for instrumentation.[62]

The battery pods could be jettisoned in case of an emergency, allowing the then-positively buoyant vehicle to rise to the surface.

Life support was provided by high-pressure oxygen cylinders in the pressure hull, with a Baralyme scrubber to remove carbon dioxide. That primary system allowed twelve hours of operating time underwater. In emergencies, two closed circuit breathing units provided an additional thirty-six hours of air for each individual.[63]

Formal launch ceremonies for the vehicle were held in Hawaii April 14, 1972, and the vehicle was certified for underwater operations to six hundred feet in late July to early August. At the time, it was reported it would be employed for marine observation and bottom photography, with a plan for later addition of a manipulator "to perform ocean engineering tasks on the ocean floor."[64]

The plan for the glass sphere did not happen, according to Murphy: "We never did develop the technology to reliably join massive glass for deep ocean use in manned submersibles."[65]

Deep View

While *Makakai* provided a fairly reasonable depth for operations with basically unlimited visibility, McLean's idea of panoramic viewing at great depths was not practical since the acrylic plastic pressure hull was designed for depths of

---

[61] Douglas W. Murphy, "The Transparent Hull Submersible Makakai," *Proceedings*, IEEE '71 Engineering in the Ocean Environment Conference, San Diego, California, September 21-24, 1971, 299.
[62] Will Forman, "Hikino/Makakai," *The History of American Deep Submersible Operations*, 263.
[63] Murphy, IEEE *Proceedings*, 300.
[64] NUC *Seascope*, September 1, 1972, 2.
[65] Murphy email to Tom LaPuzza, May 26, 2019.

a thousand feet. (Collapse depth, verified through testing to destruction of a full-sized prototype, was 4,200 feet.[66])

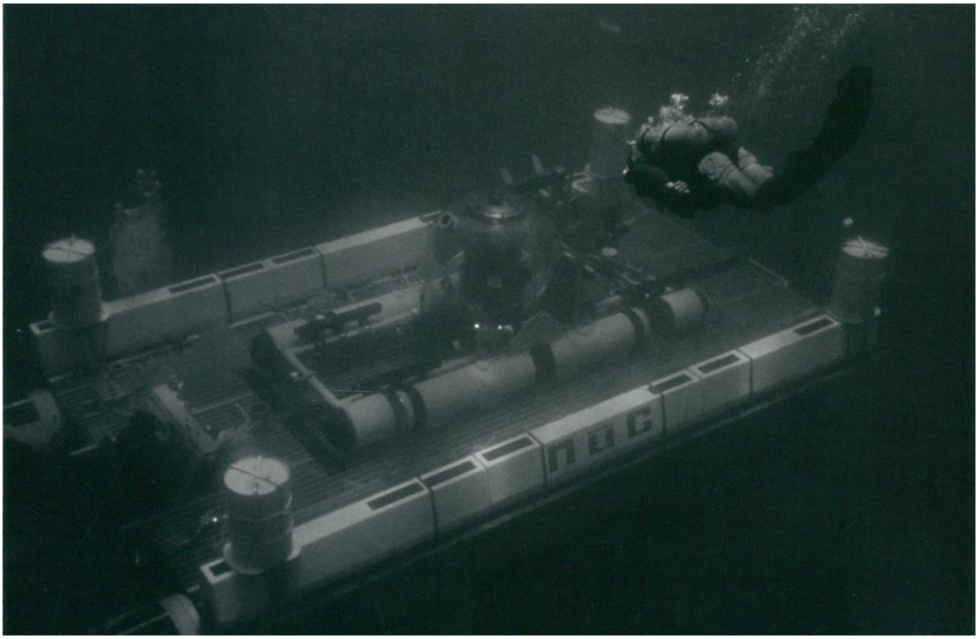
Doug Murphy had acknowledged his failure in trying to overcome the tensile weakness of glass to take advantage of its deep-sea compressive strength. On the other hand, one of his China Lake associates continued the effort. Will Forman has been introduced already as one of the pioneers in underwater vehicle development. It was an early interest with a several-decade hiatus, according to the personal statement on the back cover of his *History of American Deep Submersible Operations*. He takes the opportunity of that forum to relate his early experience as a ten-year-old, fashioning a hull from a broomstick, powered with a rubber-band-driven propeller. His ocean was his neighbor's fish pond, where he was bright enough at that tender age to add homemade "diving planes" that allowed his broomstick sub to dive and surface several times before the rubber band unwound. So far, so good. Unfortunately, his next adventure in technology was one familiar to the Navy labs in San Diego, Pasadena, and China Lake: ASW. He employed a large firecracker to attack his own sub, in the process also killing a number of his neighbor's goldfish and some of his water lilies.

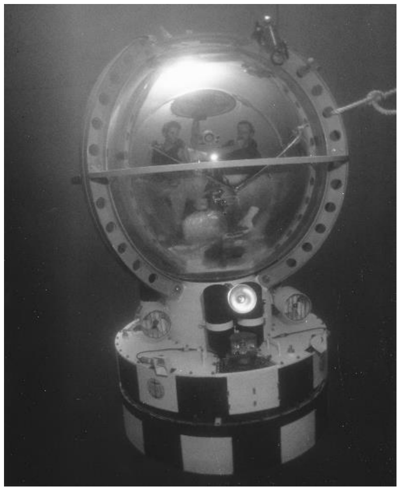
Forman's "adventures" moved from underwater to up in the air, serving as a Navy carrier pilot during World War II, after which he earned a general engineering degree at the University of Portland while remaining in the Naval Reserve. During a Reserve active-duty-for-training assignment a dozen years later, he was sent to the Naval Ordnance Test Station at China Lake. And with that bit of serendipity, he was back in the submersible business: "After a fast-paced six-month on-the-job training in underwater physics, I submitted a competitive design for a two-man deep submersible. To my surprise, I was awarded the job to design, manage, and test pilot the first American-built deep submersible."[67]

Initially the "Mobile Underwater Test Vehicle," it would become *Deep Jeep*.

After Forman completed that project and was seeking a new challenge, he attended a presentation the *Moray* team made to the NOTS technical director, Bill McLean. Following the presentation, the TD asked him to stay and wondered why he had been so "uncharacteristically quiet" during the session. In deference to his

[66] Murphy, IEEE *Proceedings*, 299.
[67] Forman, *Deep Submersible Operations*, back cover.





Center manned vehicles include *Makakai*, descending to a safe undersea lift-off from the Launch And Recovery Platform (top); *Deep View*, being christened by designer Will Forman's daughter Susan; and the Naval Experimental Manned Observatory, developed at the Naval Civil Engineering Lab by Dr. Jerry Stachiw; both came to the undersea center in the early 1970s.

colleagues, he had stifled his thought that their approach to seeking large glass hemispheres from industry for a submersible was unrealistic, in terms of both time and cost. McLean asked if he had a better solution; he did. Within a few minutes, he walked out of the conference room with $500K in funding to do what he had suggested, design a submersible around leftover forty-four-inch glass hemispheres from an AT&T transatlantic cable crossing project. They were used to "buoy the cables up where they crossed over canyons" in the deep ocean, and the ones that were unused became surplus.[68]

One of Forman's remarks at the time probably came back to haunt him frequently: "It should be a simple matter to take a hemisphere and stick a steel cylinder on the back end."

The meeting with McLean had taken place in mid-summer 1966. In mid-summer 1967, as has been mentioned several times at least, the Navy reorganized its West Coast labs, NOTS became the Naval Weapons Center, and Bill McLean left for the new Naval Undersea Warfare Center. Forman remained on the NWC payroll through 1967, continuing to live and work at China Lake, but transferred organizationally to NUWC in 1968. He transferred to San Diego the following year, during which time he worked diligently to stick a piece of steel on the back end of a piece of glass. Eventually he succeeded. The Center *Ocean Engineering* booklet offered a less "simple" approach to the use of massive glass for a portion of a pressure hull, but also indicated success:

> These problems [determination of compressive strength and a glass pressure hull design without tensile stresses in its joints] were overcome by using finite element stress analysis, statistical sampling, photo-elastic stress investigations and by using large proof and cyclic test safety factors.[69]

(On several occasions this history has portrayed the substantial value of simulation in preparing a project for prime time; in the case of *Deep View*, it didn't work. Successful testing with ten-inch-diameter glass hemisphere "models" did not scale up proportionally to the forty-four-inch real thing. Forman described one

---

[68] Shades of the Moho project I-beams used for the Simulated Distressed Submarine discussed earlier! The history of the San Diego Navy laboratory is rife with examples of engineering ingenuity, several discussed in this account. What has not been mentioned is the ability to scavenge and improvise and jury-rig, performing dumpster diving in metal recycling bins around the property to find small sheets of discarded aluminum or remnant rolls of copper wire that will perform perfectly for a prototype.

[69] Naval Undersea Research and Development Center, *Ocean Engineering*, January 1972, 3.

early test in which an explosion "equivalent to about three sticks of dynamite" resulted in the disintegration of the sphere.[70]) Nevertheless, through the precision work of a machinist on the steel component of the joint, and with the addition of stiffening rings, *Deep View* became a reality.

After a traditional christening ceremony with a champagne bottle wielded by Forman's daughter Susan, the vehicle took a brief dip off the Naval Undersea Research and Development Center Bayside pier in about forty feet of water. In February 1972 a series of dives off Santa Catalina Island successfully completed Navy certification for manned dives to one hundred feet. The testing included "evaluation of the submersible's controllability, attainable velocities, hovering and acceleration capacities, propulsion, life support, and communications systems" and involved "ten NUC codes, four other naval commands, two commercial companies, and the University of Southern California."[71]

The vehicle was transported to the Hawaii Lab, where it spent the early months of 1973 conducting a series of thirty-two dives that among other things certified three new pilots. The Center newspaper reported, "The objective of these dives was to evaluate the glass-to-titanium seal in a water environment that allowed pressure changes without temperature gradients."[72] In his own recording of the effort, Forman stated, "A month of dives were made there in conjunction with a classified porpoise program related to the Vietnam War."[73] Specific mission notwithstanding, the vehicle was returned to San Diego for demonstration dives for representatives of potential funding sources. None surfaced, and the vehicle was transferred initially to the Southwest Research Institute in San Antonio, and then put on display at the Stennis Space Center near Bay St. Louis, Mississippi.

NEMO

Dr. Jerry Stachiw, who often introduced himself by saying his name rhymed with "cashew," spent a couple of years working for the U.S. Army Ordnance Missile Command after his graduation from Oklahoma State University. He then

---

[70] Forman, *Deep Submersibles Operations*, 253.
[71] NURDC *Seascope*, April 14, 1972, 1.
[72] NUC *Seascope*, April 27, 1973, 1.
[73] Forman, *Deep Submersibles Operations*, 257.

resumed his schooling at Penn State, earning a Ph.D. in materials science, concentrating on ceramics and acrylic plastic for pressure-resistant applications. For the next half-dozen years, he worked at the Naval Civil Engineering Laboratory (NCEL) at Port Hueneme, establishing a simulation laboratory to test materials and equipment planned for use in the deep ocean.

One of NCEL's projects was testing underwater concrete chambers for durability. Installed on the sea floor, they had to be recovered every year or so for inspection and then reinstalled. Stachiw proposed development of an underwater observation device that would allow inspectors to view the chambers *in situ* on the bottom, thus obviating the need (and expense) of recovery. According to Will Forman, he turned for inspiration to Auguste Piccard, whom we met in Chapter 8.[74] Piccard had proposed in a 1956 publication titled *Earth, Sky, and Sea* that a "transparent Plexiglas [pressure hull] would present a wonderful panoramic view to the observers…" He proposed, rather than two hemispheres, the method used for *Hikino* and intended for *Makakai,* that the hollow plastic sphere be fashioned from twelve identical sections: "Their contours would be the central projection on the sphere of the twelve pentagons of a regular dodecahedron." (The exact shape, coincidentally, chosen by Naval Ocean Systems Center graphic artist Pat McCallan in designing the hardware for the Bob Hillyer-instituted Technical Director's Award in 1985. See Volume II.) Piccard expressed the hope, if not given the opportunity to fabricate one himself, that "someone will be found to take my project in hand and bring it to a happy conclusion."

That someone was Stachiw, who designed fifteen-inch-diameter scale models from half-inch acrylic to test the concept. Confident he could scale up the acrylic, he fashioned sections for two full-size sixty-six-inch-diameter models two-and-a-half inches thick and found an appropriate glue to join them. Testing demonstrated required structural strength, and "the calculated collapse depth was confirmed by destruction under pressure of one of the full-scale prototypes at 4,150 psi."[75]

Somewhere in the process, a title was developed that would have tickled Jules Verne: "NEMO," the Naval Experimental Manned Observatory.

Three of the Stachiw-designed hulls were fabricated by a contractor, each from ten curved acrylic pentagons with the "top" and "bottom" left open for the passenger entrance/exit hatch and for pass-throughs of electronics cabling and

---

[74] Forman, *Deep Submersibles Operations,* 223-4.
[75] Forman, 224.

attachment to the foundational housing for batteries and the haul-down system. The latter featured a four-hundred-pound anchor device attached to a two-horsepower winch that both lowered the pressure hull to the bottom and brought it back up to the surface via a cable. The eight-cubic-foot ballast tank was fashioned as the connecting structure between the spherical pressure hull and the cylindrical housing.

When the actual submersible was fabricated, the pressure hull was mounted on the cylindrical base and reinforced with three curved vertical structural beams and a horizontal one around the "equator."

Following hydrostatic testing at Southwest Research Institute in San Antonio, Texas, sea trials were conducted in the Bahamas in the spring of 1970, generally to about six hundred feet, with one to seven hundred and twenty. Certification of the submersible coincided with inspection of the NCEL underwater concrete test structures in the Santa Barbara Channel in 1972. Several months later, the vehicle was transferred to the Naval Undersea Center, where Dr. Stachiw had moved in 1970. The materials engineer would have a substantial impact on Center ocean engineering programs for the next quarter century.[76]

Increased Navy concern about submersible safety stimulated a "rebuild" of the vehicle that included a new fusing system and fusing protocol and overhaul of the hydraulic systems. The intent was to do some "useful work with it," according to Bob Watts, who supervised recertification for manned operation after the overhaul.[77] Watts made a certification dive to six hundred feet at San Clemente Island, and after "reams of documentation on how everything was built, tested, certified a piece at a time… it all came together with that test dive…"

He added the "useful work" included Dr. Scott Johnson performing *in situ* research involving sharks and various other fish, "and we actually did about a month-long operation out at San Clemente Island using NEMO as the observing platform for some of that work." The Center newspaper reported on the studies, conducted in mid-January 1973, with the submersible hovering at a depth of approximately a hundred feet. It noted previous extensive shark research had been

[76] Outstanding among Stachiw's contributions is the massive eleven-volume "monograph" he compiled and the Naval Ocean Systems Center published in 1990, "NOSC: Ocean Engineering Studies," in which he devoted seven large volumes to the use of acrylic plastic for undersea pressure housings, two to concrete as the pressure-resistant material, and one to glass.

[77] Bob Watts interview II, 2-3.

conducted by Johnson and other members of his group, but always on or very near the surface. The shirt-sleeve-environment submersible allowed up-close-and-personal observation and photography of "feeding habits and behavioral patterns of sharks and various species of marine mammal life in the area."[78]

Following those studies, NEMO was also transferred to Southwest Research Institute for a time and then went out in a blaze of glory as a stationary exhibit in front of the submarine ride at Disneyland.

Why Man?

Dr. William B. McLean, as noted several times earlier, was vocal in his belief, and liberal in his funding for that belief, that human interest, and the Navy's military interests, required humans to work in the depths of the sea. His early efforts to achieve that were only slightly hampered by his local environment of the Mojave Desert, so he used swimming pools, small man-made reservoirs, and slightly distant mountain lakes to simulate the ocean that was nearly two hundred miles away. When sponsors were hesitant to fund what he viewed as a critical need for expansion of presence and capability into the oceans, he gave speeches and interviews, wrote papers, testified to Congress. As TD, he had a certain amount of discretionary funds, often Independent Exploratory Development monies, which he provided to those close to his sentiments (Don Moore and Will Forman are prime examples) to pursue his or their own fascination with the underwater world.

Shortly after he became the first technical director of the Naval Undersea Warfare Center, he appointed Howard Talkington head of a new department focused on ocean engineering. One would imagine such an organization had a clear mandate for and expectation of developing underwater systems, particularly vehicles of various kinds. Talkington also believed in the value of such systems, but his thinking diverged somewhat from that of his boss. In a Naval Undersea Center Technical Note in February 1973, challengingly titled "Why Man?" he stated quite clearly from the outset, "The thrust of this paper is that, although manned systems are useful, exciting, and, many times, necessary, the majority of

[78] "NEMO Employed For Shark Studies," NUC *Seascope*, January 19, 1973, 1.

undersea tasks facing man can be accomplished more safely, economically, and as thoroughly with unmanned systems."[79]

He followed that up with three examples illustrating the applications and values of each:

--Exploration, for which he cited the bathyscaph *Trieste*, although somewhat unrealistically since, despite its unmatched ability to descend to the deepest depths, it was unable to move much distance there. Better examples would have been *Makakai* and *Deep View*, assuming Continental Shelf-depth bottoms.

--Search and recovery: here he cited the much more credible recovery by CURV of the hydrogen bomb, suggesting this as a capability applicable to manned and unmanned systems.

--Work: CURV again, this time CURV III and the work at the Azores range discussed earlier in this chapter. What he added to that was a nicely concise description of the many roles an underwater work system could (and did) play in such a scenario:

> … rigging one of the 125-foot acoustic towers so that it could be lifted from the sea floor, cutting various undersea electric cables that were from 1.5 inches to 3.5 inches in diameter, retrieving underwater electric cables from the ocean floor… sonar mapping of the acoustic tower sites, and inspecting the underwater range once all the other tasks had been successfully completed.[80]

Using as an example of contrast climbers planting a flag atop Mt. Everest versus dropping one from a plane flying over it, Talkington acknowledged the innate human desire to arrive, physically and/or psychologically, at some geographic location or personal goal. He also recognized circumstances dictating the necessity of putting humans underwater, but cautioned, "When man is put into a system there must be a specific, necessary purpose for having him there, and he must achieve that purpose."[81]

His conclusion, one demonstrated with the variety of systems developed in his department, was:

> First, it is recognized that, to meet the challenge of making a thorough and effective use of the marine environment and its resources, a full complement of manned and unmanned systems will

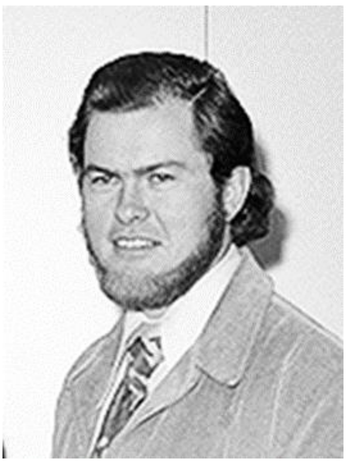
---

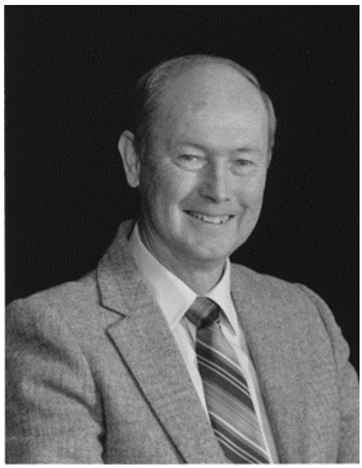
[79] Howard R. Talkington, "Why Man?" Naval Undersea Center Technical Note 953, February 1973, 1.
[80] "Why Man?", 5 & 7.
[81] "Why Man?", 10.

be required. Second, it is, however, imperative that unmanned systems be used as much as possible.

He cited six reasons for the preference, including unlimited on-site endurance, personnel safety, and cost savings. In his 2012 interview, Bob Watts explained the savings concept:

> Bill McLean had a special interest in being able to do things with men in the ocean. The reason it really didn't go anywhere is because you can build an unmanned system with manipulators and TVs and sonars, virtually all of the things you could have on a manned submersible except having a man right there at the site. And you can do it for ten cents on the dollar, because about ninety cents of every dollar—I would say at least eighty cents on the dollar—for manned submersibles is spent keeping the people alive, and making sure that you get them back. So it's much more cost effective to use unmanned systems.[82]


Bob Watts


Howard Talkington

HRT

Several times earlier in this chapter, Ivor Lemaire has been quoted about the efforts of his boss, Howard R. Talkington, in publicizing the capabilities of the

[82] Bob Watts II, 6.

undersea center to support underwater testing and ocean technology development. Nowhere was that more evident than the Ocean Engineering Demonstration of 1971. Talkington brought together many of the vehicles discussed above and below, plus an array of undersea and surface capabilities, orchestrating a detailed plan to market the Center. He invited numerous potential sponsors and the news media to San Clemente Island to gape and exclaim at the substantial variety of those capabilities. Given that his was a soft-spoken, deeply religious, introspective personality, it almost seemed a little uncharacteristic of him. On the other hand, given that most of his employees called him "HRT" instead of "Mr. Talkington," and given his strong desire to contribute substantially to the Center's success, it was not out of character in the least.

It is difficult to overestimate the contributions of Howard Talkington to the field of ocean engineering. With a civil engineering degree from the University of Southern California, he came to the Pasadena Lab in 1951 as a Junior Professional. His first projects, study of a weapons launcher at Morris Dam and project engineer for the Anti-Submarine Rocket, were typical mechanical engineering-related assignments at the Center. Fairly early in his career, however, he was selected to head the Advanced Planning Branch and charged with developing San Clemente Island into a major undersea test and evaluation range. That would provide the major direction for his career, and propel him to leadership of an entirely new discipline: ocean engineering.

In his interview, Ivor Lemaire said that first "branch" headed by Talkington, his sole supervisor during three decades of Navy laboratory employment, consisted of the two of them and one other employee. Their tasking was "to basically get out there and make sure that San Clemente Island was used properly, and to try to plan for the follow-on to CURV [Cable-controlled Underwater Recovery Vehicle]… And that was the sort of genesis of ocean engineering."[83] Asked by the interviewer if this represented Talkington "essentially inventing ocean engineering," he responded, "Essentially, that's right."

In the foreword to a volume Talkington would write several decades later for a planned series on the subject, the editor, Neil T. Monney of the U.S. Naval Academy, wrote:

> The key to opening the last frontier on earth rests in the hands of the ocean engineer. Ocean scientists provide the fundamental knowledge of the physical, chemical, and biological characteristics of the ocean environment. It is the task of the ocean engineer to build on this

[83] Ivor Lemaire interview, 7-8.

> knowledge and provide the hardware systems that can unlock the enormous wealth of ocean resources.[84]

Howard Talkington was just the individual to do that. Championed by his department head Devirl A. "Bud" Kunz, he was placed in charge of the CURV mission to recover the hydrogen bomb. Given the circumstances (a Navy flag officer in charge, who was not given the appropriate equipment to handle the task since none existed, and who thus was substantially displeased with the whole operation and even more displeased by all the civilians around; months on station by multiple ships and hundreds of Navy personnel; no discernible progress), Talkington was in probably the most tension-driven position on the Mediterranean Sea for several days. Nevertheless, he managed his personnel effectively and they succeeded. He was presented the Navy Superior Civilian Service Award for his leadership of the effort, which he undoubtedly deserved.

He went on to manage Center deep-ocean engineering efforts, including the Submarine Rocket program (an attempt, somewhat unsuccessful, to migrate the Anti-Submarine Rocket into an undersea-launched weapon). His work ethic pleased the technical director, Bill McLean, enough that he established a department and put him in charge of it. (Actually, he wanted the department anyway, and he viewed Talkington as the perfect manager for it.) Ivor Lemaire, substantially appreciative of his mentoring, noted the reasons for that: his calm and respectful manner toward all ("… just a total gentleman. I never heard him swear, ever, at anybody or anything,") and his meticulous habit of keeping on top of things ("… he was just really totally organized. In fact, Wally Hicks [deputy to Doug Wilcox] would say, 'I could never be that organized, Ivor. How does Howard do it? He has notes for his notes.'"[85])

HRT supervised the Ocean Technology Department for twelve years, during which time he also attended the Harvard Advanced Management Program and wrote a "guide book and reference for persons interested in undersea systems" (*Undersea Work Systems*).

While managing his own department in the early 1980s, he was also tasked, during an interim period, with the rather arduous assignment of leading Central Staff, for which he was presented the Navy Meritorious Civilian Service Award at a change-of-command ceremony in June 1982. Several months later he was

---

[84] Howard R. Talkington, *Undersea Work Systems,* Ocean Engineering Series 1 (NY: Marcel Dekker, Inc., 1981), v.

[85] Ivor Lemaire interview, 8-9.

promoted to director of the Engineering and Computer Sciences Directorate.[86] Interestingly, when Talkington assumed that position, ocean engineering projects and people he had previously supervised for more than a decade in another directorate were as if by magic transferred to the directorate he now managed.

One of the founders of the Marine Technology Society, which started with a Los Angeles chapter during the time he worked at the Pasadena Laboratory, he was named an MTS Fellow in 1984. He consistently served on and chaired MTS committees over the years, and received the MTS Lockheed Award for Ocean Science and Engineering, presented at the same time as his fellowship induction. Several years later he received the society's Distinguished Service Award.

In January 1987, Talkington was selected as associate technical director, succeeding Doug Wilcox, who had served in that position for the first decade after the establishment of the Naval Ocean Systems Center.

In November 1993, in desperately failing health, HRT was presented his second Navy Superior Civilian Service Award, the citation noting, "Through your continuous, astute perception of applying technological principles to national objectives within the environment of the ocean, you qualify as a mentor of ocean technology and engineering."

He passed away a month later.[87]

Unmanned vehicles

Mechanical engineer Don Endicott, who would one day be a Senior Executive Service department head at the Center,[88] graduated from the University of California at Santa Barbara, "connected to the environmental community" and determined to "do environmental things," a la Jacques Cousteau. He made it clear

---

[86] As will be detailed in Chapter 15 and Volume II, the merger of NELC and NUC into the Naval Ocean Systems Center presented the management challenge of too many departments. That problem was solved by inventing "directorates,' which were more or less "super departments."

[87] Naval Command, Control and Ocean Surveillance Center RDT&E Division *Outlook*, November 5 and December 17, 1993, 1.

[88] Senior Executive Service positions, previously termed Public Law positions, were high-level federal civilian positions, equivalent to the military rank of admiral or general.

to Center recruiter Jim Price he had no interest in working for the Navy. Price, who had been Endicott's teaching assistant early in his college years, persisted, suggesting he merely take the half-day drive to San Diego and look around the Naval Undersea Center. Endicott's reaction was immediate, and positive:

> It was like Santa's workshop. They had this flying spar buoy and some other far-out projects. I forget some of the names, but it was hands-on and they even had a machine shop in back so you could even be involved in building your designs. It was Buck Rogers plus Jacques Cousteau plus anything goes and I was sold right then.[89]

The lure of working on "far-out projects" was a substantial selling point to a goodly number of the college graduates recruited under the Junior/New Professional program in the late 1960s and throughout the '70s. And arguably the interest was strongest in designing undersea vehicles of various shapes and sizes and uses.[90] The "family" of Cable-controlled Underwater Recovery Vehicles represented the most visible of those, but there were more than a few others to intrigue inquiring young minds and to compensate for government salaries that were certainly less than private industry offered. (And at the time, private industry had no interest in developing submersibles, seeing little value in them.)

Snoopy

Bruce Fugitt approached his branch head, Ivor Lemaire, with an idea for a small submersible, seeking funding to develop his concept to see if it would work. Comparatively speaking, it was nothing like CURV; Fugitt envisioned a vehicle he could pick up and carry down to the pier or the beach (there were several accessible at NUC's waterfront) and place in the water for a test dive. Also unlike CURV, it had no vertical thrusters. Instead, Fugitt designed a vehicle whose main component was a cylindrical buoyancy tube about four feet long. A hydraulic piston inside that tube allowed the vehicle to dive, hover, and ascend to the surface based on the position of that piston (and thus, how much sea water was inside).

Propulsion would be provided by two small hydraulic motors, and a

[89] Don Endicott Oral History I conducted by Tom LaPuzza, June 21, 2012, 2.

[90] According to retired Executive Director Carmela Keeney, who worked in both areas: "The hardest place [at the Center] to get a job was the OE [Ocean Engineering] and marine mammal groups because of their tremendous popularity."

lightweight cable would carry command signals to the piston, the motors, and the main focus of the device, a television camera. A small light illuminated scenes under piers or at depths where lighting was insufficient for viewing the camera's findings.

Fugitt received his funding and designed the device, which he named "Snoopy," with the assistance of Rich Uhrich and Jimmy Held. It was built in the Center's machine shop. As the *Seascope* headline made clear, "Snoopy Substitutes For Non-Divers," meaning those folks mentioned earlier who would love a peep underwater but eschewed face masks, flippers, and air tanks.[91] A fairly uncomplicated control box with a joystick allowed even a novice to guide the fifty-pound vehicle around pier pilings, under boats, or down to about a hundred-foot-deep seafloor. The buoyancy piston was of greatest value in the latter venue, since the traditional vertical thruster was notable for stirring up clouds of sediment that had to settle before the operator could view the scene. *Snoopy*'s operator could do that via a monitor set up on a pier, providing up-close-and-personal views of the underwater world, all without even getting one's feet wet as the vehicle scooted along a few inches off the bottom with no cloud of dust to hinder viewing.

Despite *Snoopy*'s success, Center engineers are seldom satisfied with the current model of their creation. Consistent with that paradigm, *Snoopy* underwent several modifications in the first years of its existence, gaining a sturdier, lighter frame of anodized aluminum; a compass; and a small grabber device that could retrieve objects weighing a few pounds. Also added was automatic depth control, allowing the operator to set a predetermined depth to which the vehicle would dive and hover, and a specially designed transport box for traveling.[92]

The following year, an entirely new vehicle with a substantially different design was put into the water: Electric *Snoopy*, designed by Marion McCord, was significantly heavier, at a hundred and fifty pounds, and was equipped with a TV camera and an 8mm cine camera. Most significantly, the buoyancy tube was replaced with the standard vertical thrusters. The vehicle could reach depths of 1,500 feet.

[91] NURDC *Seascope*, October 15, 1971, 1.
[92] NUC *Seascope*, February 2, 1973, 3.

Bruce Fugitt was able to carry the original *Snoopy* to launch off the pier by himself, but Marion McCord's Electric *Snoopy* required both of them.

Reasonably since NUC was the only game in town at the time in terms of submersible design and development, the Naval Facilities Engineering Command (NAVFAC) requested a similar vehicle, seeking a craft for non-diver inspection of underwater construction sites. About the same size as the electric version at four feet in length and two feet in width and height, NAVFAC *Snoopy*, as it was termed, weighed twice as much at three hundred pounds and was equipped with four thrusters. Major improvement was addition of a sonar system.

Rescuing the "big guys"

As has been described in some detail in several chapters, the intent of the "heavy duty" submersibles like CURV was the location and recovery of large objects, while the *Snoopy* line of vehicles was designed to perform basically underwater inspection-type tasks. In an interesting turnabout, both CURV III and its Hawaii Lab cousin the Remote Unmanned Work System (RUWS) were recovered from the sea floor in mid-1979 with the assistance of NAVFAC *Snoopy*.

CURV had been operating in about four hundred feet of water fifty miles off the California coast near Port Hueneme, inspecting a target mooring. It became entangled in polypropylene line that lodged in its propellers. During an effort to free it, its control cable broke. Although positively buoyant, it remained on the bottom, tangled in the line. Bad weather and lack of appropriate surface support craft foiled the first two recovery attempts.

In mid-July, submersible crews from the Center's Ocean Technology and Fleet Engineering departments teamed to recover the vehicle, with NAVFAC *Snoopy* locating the long-lost vehicle (operated by none other than CURV III primary operator Larry Brady) and the CURV II range recovery craft operated by Bob Smith cutting the polypro line. The freed CURV III, still positively buoyant, rose to the surface three hundred yards away.[93]

Out in Hawaii, RUWS had been involved, for the second time, in attaching a line to recover the lost anchor and chain of a Navy ship, this time USS *Ashtabula* (AO-51). The fleet oiler had lost her starboard anchor and more than a thousand feet of anchor chain. RUWS had attached the line and the recovery was complete when the submersible's shock absorber system failed, marooning it on the bottom in about four hundred feet of water off Pearl Harbor. NAVFAC *Snoopy* was flown in from the mainland, deployed from the work platform SSP *Kaimalino*, and attached a Kevlar line to allow recovery. RUWS had only minor damage and was back in operation shortly thereafter.[94]

SCAT and telepresence

A parallel project to the original and electric versions of *Snoopy* was one of several efforts, both in San Diego and Hawaii, to develop "telepresence," the sense that a human being safely and comfortably seated on a dock or the deck of a ship was underwater, on the bottom, performing useful work on-scene but without the face mask and the mouthpiece. San Diego ocean engineers designed the Submersible Cable-Actuated Teleoperator (SCAT), a two-thousand-foot-depth remotely operated vehicle, as a testbed for the head-coupled TV to provide that

---

[93] Naval Ocean Systems Center *Outlook*, July 13, 1979, 2.
[94] NOSC *Outlook*, July 27, 1979, 1.

sense.[95] In this concept, one of a variety of "helmets"—the first a prototype concoction of Styrofoam, Velcro straps, and binocular-looking viewing tubes—was worn by the vehicle's operator sitting in a chair on the dock. The "helmet" was intended to disconnect him/her from the chair and the dock and sights and sounds of the coastal environment. Instead, the eyes were seeing the ocean floor and the head in swiveling left-right-up-down moved the underwater camera correspondingly. The news was all good: the human was not cold or wet or worried about breathing, but was for all practical purposes on the bottom in terms of sight and head movement. Sight indeed was "binocular," seen from two "eyes" an inch or so apart (thus generating depth of field).

A decade later a second SCAT, about the same size at six-by-four-by-four feet, but more than twice as heavy at a thousand pounds, served as an inspection platform, capable of operation to depths of three thousand feet. *Snoopy* could lift and carry a package weighing four pounds; SCAT's payload was eighty pounds.

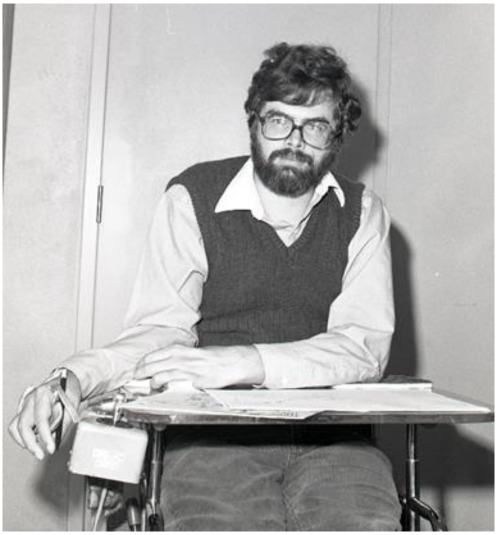
Rich Uhrich

As noted above, one of the designers of *Snoopy*, and also significantly involved in the head-coupled TV work, was Rich Uhrich, whose story reflects as much about the compassion as the creativity of the San Diego ocean engineering group. Uhrich, a 1964 graduate of the California Institute of Technology, moved a couple of miles east to the Pasadena lab as a Junior Professional (JP). As typically expected of JPs, he returned to school at the University of Southern California, earning his master's degree in machine design in February of 1968. Two months later, on a Friday afternoon, he packed his desk in Pasadena, anticipating arriving at his new work site at the Hawaii Lab Monday morning. He never made it.

Early Sunday morning he was critically injured in a traffic accident that left him paralyzed from the neck down. Tragic end of story? Not by a long shot. A *Seascope* on August 30 stated, "Rick still expects to go to Hawaii." A year later, the paper reported, "Uhrich returns to work." With support and even insistence from his branch head Dick Heller and Personnel Office's Marion Kelly, he came back, his body (except some limited right-hand movement) paralyzed, but his

[95] "Naval Ocean Systems Center Underwater Vehicle History," NOSC TD 1530, April 1989, 18.

mind as brilliant as ever. Somehow, he "developed a remarkable ability to conceptualize solutions to complex engineering design problems."[96]



Rich Uhrich

He also continued his "doodling," penciled drawings that had illustrated his Caltech class notes, to such a degree his good friend Bruce Fugitt asked for some of his drawings, signed, to hang in his new apartment. Fugitt and the staff of the Ocean Engineering Division not only encouraged but casually checked in on him scores of times a day to ensure he was all right and had the tools needed to work: "One of the greatest aspects of my work is that my friends are close by, ready to help me if I need it," he told a reporter in 1981. "Without them, I couldn't work."

A better end to the story: In 1985, Uhrich was presented the Office of Personnel Management, Department of the Navy, and Department of Defense Federal Handicapped Employee of the Year awards.[97] Uhrich retired in the mid-2000s, with nearly forty years of federal service.

Vehicles with varied applications

The decade of the 1970s was most productive for Center ocean engineers in

[96] NOSC *Outlook*, May 20, 1983.
[97] NOSC *Outlook*, September 6, 1985.

terms of the undersea vehicle development. Early on, the *Snoopy* and SCAT vehicles were launched. In the decade's later years, when the Naval Undersea Center merged with the Point Loma electronics lab to form the Naval Ocean Systems Center, vehicles were produced for mapping the sea floor, lifting heavy weights from it, simulating submarines, and recovering rockets from outer space.

The Real-time Optical Mapping System (ROMS) completed its first ocean testing off San Clemente Island in early 1978, resulting in "high optical resolution [images] covering a large swath width with a readout showing real time optical pictures of the ocean bottom."[98] Project manager Paul Heckman reported the test demonstrated "we have successfully bridged the gap between existing acoustic systems which provide long range and real time operation but are limited by low resolution, and photographic systems which offer high resolution but are not capable of real time operation."

Heckman employed an argon ion laser for the light source. In the January 29, 1969 *Seascope,* he detailed work in "underwater optical range-gating," reporting the *Thresher* disaster had emphasized shortcomings of conventional underwater lighting, as "searchers …could only see about 15 feet… With laser range-gated equipment, primitive as it is yet, we have identified objects in unlighted clear water up to 131 feet." ROMS scanned at a height of a hundred and twenty feet above the sea floor, with a swath width of four hundred feet, producing high-quality images.

For more than thirty years and a hundred and thirty-five missions, NASA's five Space Shuttles carried America's astronauts (and a number from other countries) into space on a wide variety of assignments. The shuttles were obviously reusable, as were the boosters on which they depended to get into space: "The Solid Rocket Boosters (SRBs) operate in parallel with the main engines for the first two minutes of flight to provide the additional thrust needed for the Orbiter to escape the gravitational pull of the earth."[99]

The SRBs weighed 193,000 pounds empty, and carried 1,107,000 pounds of propellant, basically dry aluminum powder mixed with oxidizer, catalyst, and binder to form a substance similar in composition to hard erasers. At an altitude of approximately twenty-four nautical miles, their fuel depleted, the SRBs were jettisoned from the orbiter and they dropped into the sea, their descent rate

---

98 NOSC *Outlook*, March 10, 1978, 1.
99 NASA web site: https://www.nasa.gov/returntoflight/system/system_SRB.html visited June 8, 2019.

controlled by parachutes. Upon impact, the empty boosters filled partially with water, floating in a somewhat vertical orientation.

Reuse of the booster rockets was a critical part of the operation, making their efficient recovery essential. In 1975, NASA asked the Naval Undersea Center to design a system to pump out the water, floating the hundred-and-thirty-foot-long by twelve-foot-diameter boosters like massive tree logs for ease in towing to port for refurbishment and reuse.

The SRB Dewatering System, alternately the NASA Nozzle Plug, consisted of a powered submersible shaped like a plug with an expandable collar, a control console, and support sub-systems. A television camera provided the operator's eyes underwater, as he employed four horizontal and two vertical thrusters to maneuver the vehicle into position. Once the plug was inserted into the bottom of the booster, three hydraulic locking arms secured it into place in the nozzle (source of the fiery exhaust at launch), and compressed air was blown in, forcing the water out. With most of the water gone, the empty booster rolled over into the horizontal 'log' mode for towing to port.[100]

In addition to the dewatering system, NUC "developed a total retrieval scenario and performed the necessary studies leading to a retrieval concept that was adopted by NASA," according to program manager Art Schlosser.[101]

As NASA prepared for its first shuttle launch, the Air Force announced it would also participate, responsible for polar launches from its Vandenberg base in California. With the Center assigned similar support, the Air Force adopted the NASA retrieval concept. In early planning, however, undersea center personnel analyzed the Vandenberg launch scenario and concluded the two-recovery-ship plan was unnecessary. Rather, a single self-propelled barge, based at Port Hueneme, was determined more cost-effective. Based on that analysis and changes in recovery platform, NUC saved the Air Force ten million dollars.

Remote Unmanned Work System

In establishing the Hawaii Lab, Bill McLean had offered an opportunity to

[100] NOSC *Outlook*, May 6, 1977, 3.
[101] NOSC *Outlook*, May 9, 1980, 1.

China Lake and Pasadena engineers to travel to an exotic location to do meaningful work. They had responded by proposing working with marine mammals and developing underwater work systems. In actuality, the first mechanical engineers moving to Hawaii were tasked with supporting the marine mammal effort. In a brief time, however, the submersible work begun at Pasadena with the original CURV and at China Lake with *Moray*, *Deep Jeep*, and *Hikino* emerged as the second major product line of the island laboratory.

Dan Hightower, one of the original handful of transfers, found himself in short order managing development of both the Stable Semi-submerged Platform and a new, deep-ocean underwater vehicle. As noted in Chapter 11, Deputy Technical Director Doug Wilcox told him he could choose which program to manage, but only one of them. Hightower chose the underwater vehicle.

The Remote Unmanned Work System (RUWS) vehicle was in some respects similar to the later CURV family craft: it was slightly smaller in physical dimensions, but about twice as heavy; it was controlled by a cable; and operators worked from a control van on the deck of a ship. The first of a number of substantial differences, however, was the design depth of 20,000 feet, versus the various CURVs designed for 5,000 to 10,000 feet. RUWS designers recognized the power required and the potential problems inherent for a submersible towing a fifty-five-connector coaxial cable thousands of feet long, and developed a different concept: a second underwater platform, called the Primary Cable Termination (PCT), was designed, nearly the same size as the work vehicle. As clearly stated in its title, it served as the end point for the thousands of feet of primary cable bringing down power and control functions. A secondary cable, on the order of several hundred feet long, allowed the vehicle itself access to tens of million cubic feet of ocean without dragging a heavy cable. If that volume proved insufficient, the PCT had its own propulsion system and could be moved to increase the "reach" of the submersible vehicle.

According to Hightower, RUWS

> innovations included the first use of Kevlar for the strength member of the control cable. The Kevlar-epoxy strength members were contra-helically wrapped around a coaxial cable on which power, television signals, and controls were multiplexed. The result was an inch-and-a-half-diameter cable that weighed 17,000 pounds. This relatively light weight allowed RUWS to meet an important goal of air transportability and use on non-dedicated ships.[102]

[102] Dan Hightower email to Tom LaPuzza, January 26, 2012.

Naturally, Bill McLean had an abiding interest in the Hawaii undersea work, providing general recommendations to his ocean engineers he expected them to pursue in whatever direction seemed reasonable. According to Hightower, "He wanted us to develop new control/display technology so the operator would believe he was literally there on the bottom. That's when we first started using terms like 'remote presence,' 'telepresence' and 'teleoperation.'"

As noted above, the San Diego engineers working on SCAT succeeded in demonstrating a head-coupled TV, but the successful effort in a laboratory environment in Hawaii failed to translate to similar success on RUWS. What was effective, however, was a design for mimicking human dexterity, such that "the person using the manipulator would slip his hand into a controller and then operate the manipulator on the vehicle with normal hand and arm movements."

In regular operations, the RUWS vehicle was placed atop the PCT, and descended piggyback to the work site, the PCT dropping relatively vertically to the desired depth. There it provided a stabilizing force that supported station-keeping and limited dynamic forces that might otherwise have affected vehicle movement. A specially designed motion-compensation system, detailed below, minimized the effect of surface waves on the control cable. At working depth, the vehicle "swam" off the termination platform, trailing only its short control cable, and performed required tasks before settling back on the PCT for return to the surface. The use of blocks of syntactic foam for buoyancy, initiated with China Lake's *Moray* and continued with later models of San Diego's CURV, was also a design feature of the Hawaii deep submersible.

RUWS made a series of developmental dives for half a dozen years in Hawaiian waters, at the same time participating in several real-world assignments: recovering the massive anchors and lengthy anchor chains of two fleet oilers which had to remain at the dock until that equipment was recovered and reinstalled, and participating in a classified project requiring instrument placement in water depths exceeding diver capability.

In January 1980, the vehicle and its PCT were performing a developmental dive to 15,500 feet, when the shock absorber at the end of the primary cable failed, wrenching it free of the PCT. Both the termination platform and vehicle were lost. The sole bright spot was the fact the cable was recovered intact. It was employed as the initial control cable for the next Hawaii deep-ocean vehicle development, the Advanced Tethered Vehicle.

High-danger times: launch and recovery

The most dangerous time and place in the life of an undersea vehicle is not lurking in the ocean's cold, dark, bone-crushing-pressure depths, but rather on the surface as it is being swung over the side of its support ship to begin its dive, or winched aboard to conclude it. Those are the tensest moments for the humans who build and operate the craft, as they view the vehicle into which they have poured so much time and money and probably even affection, swinging wildly at the end of a long crane cable above heavy seas, threatening to smash against the unyielding hull of the ship to become almost instantly so much marine junk.

Efforts of the ocean engineers in both San Diego and Hawaii to develop exotic and practical new undersea vehicles had to include of necessity an even more practical plan to get those vehicles into and out of the water without mission-ending damage. Norm Estabrook started those efforts in the very early 1970s, with a fairly straightforward idea: build a submersible platform, put the undersea vehicle on the platform in the calm waters of a bay or harbor, tow it to sea, and submerge them both. Then, in the quiet water ten or twenty or a hundred feet down, "swim" the submersible off the platform, perform the undersea mission, return it to the platform, and reverse the process.

Estabrook's project was called, simply and quite aptly, the Launch And Recovery Platform (LARP): "I was the project engineer and did the general design, the lay-out… With funding from Dr. McLean's internal resources, I copied [Oceanic Institute naval architect] Hank [Horn's] basic design, and then added several improvements…"[103]

With engineering technician Gerald Ching, he designed a catamaran-like platform consisting of two thirty-five-foot-long, four-foot-diameter cylindrical hulls fabricated of fiberglass by a contractor specializing in sewer pipes. Personnel in the Pasadena machine shop manufactured the aluminum crossbeams that connected the two hulls, and assembled hulls and crossbeams to ensure correct fit before disassembly and shipping to Hawaii. There the hulls were fitted with five ballast tanks each, the crossbeams were attached to connect the hulls, and a deck of lightweight aluminum was added.

[103] Norm Estabrook SSC Pacific oral history interview conducted by Tom LaPuzza January 5, 2012, 4.

A sixty-five-foot tether deployed from a surface buoy as the platform sank; when the tether was fully deployed, the platform descent stopped. The surface buoy marked its location underwater.

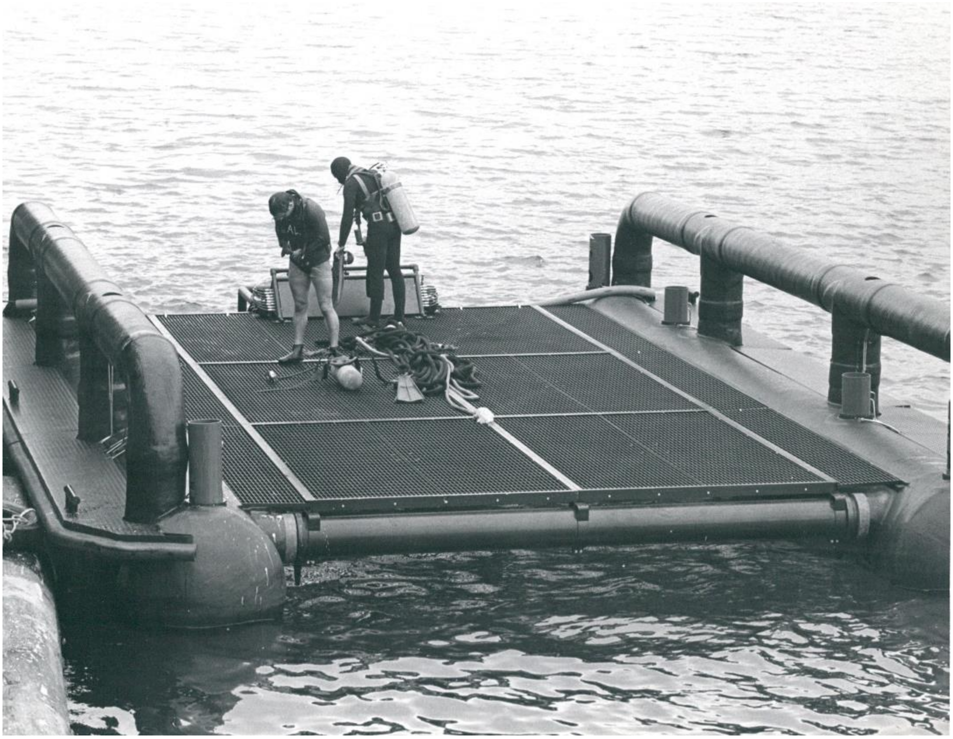
Development timing was such that LARP was one of several Hawaii Lab projects shown off during the ocean engineering demonstration at San Clemente Island in September 1971. More importantly, the film produced for that demonstration, *Eyes of Inner Space*, concludes with an exciting scene of CURV III "landing" aboard, and, accompanied by a music crescendo, LARP rising dramatically to the surface, Estabrook in full dive regalia at the controls.

(The Hawaii Lab also produced a much more complex launch and recovery capability, which will be discussed as part of the Advanced Tethered Vehicle program in Volume II.)

Supporting Special Forces

Navy Special Forces personnel have a variety of missions, most of them intentionally behind-the-scenes and out-of-sight. A crucial one is going ashore unnoticed to perform some clandestine operation and leaving again without being seen. "Locking out" of a submarine and employing Swimmer Delivery Vehicles (SDVs) to get ashore and back to the sub is the optimal approach.[104] The obvious problem is that training is critical to performing those missions successfully, and the Navy cannot afford to assign operational submarines for training purposes. Enter ex-Navy SEAL and ultimate triathlete Ron Seiple. (Among his other feats, Seiple completed the Ironman Triathlon of a 2.5-mile ocean swim, a 112-mile bike ride, and a full running marathon. See NOSC *Outlook*, February 23, 1979.)

[104] Interestingly, those vehicles, reasonably a project for an organization like the Navy's coastal systems lab in Florida, were developed and produced by the Naval Weapons Center at China Lake. Robert M. Hillyer oral history interview conducted by Tom LaPuzza, August 21, 2013, 8-9.



The Submersible Training Platform provided Navy Special Forces personnel a realistic platform from which to practice underwater deployment with swimmer delivery vehicles to perform clandestine near-shore missions.

Recognizing in the LARP a possible resource for Special Forces personnel (and in fact LARP was loaned to the Underwater Demolition Team West Coast Detachment for about a year), Seiple designed a similar device titled the Submersible Training Platform (SUBTRAP): "The SUBTRAP served as the deck of the submarine as it was towed underwater by a surface craft. Back then it was next to impossible to get submarine service and SUBTRAP worked as an excellent backup."[105]

The platform allowed SEAL (Sea, Air, and Land) teams to "ride" submerged with their SDVs, launch off while in motion and go ashore, perform their training mission, and return to the "sub." The twenty-four- by thirty-six-foot SUBTRAPs

[105] Ron Seiple email to Tom LaPuzza, March 30, 2019.

were a ruggedized version of the launch platform, with similar fabrication from

> two longitudinal fiberglas [sic] pontoons braced and joined by four aluminum cross members. Control consoles on each face aft so the diver-operator can check trim during submerging and surfacing operations. Submergence is performed by flooding the pontoons, and each platform has bottles of compressed air for blowing the tanks to surface.[106]

The Hawaii Lab contracted for two SUBTRAPs to be fabricated and delivered to the Atlantic and Pacific Fleet special forces units. The *Outlook* story noted that "total fabrication and maintenance costs for SUBTRAP are less than several days' operational cost for a fleet submarine," none of which was ever available for this purpose anyway.

In a class by itself

Perhaps the ultimate in manned underwater vehicles were the commissioned U.S. Navy submarines assigned to the Center. As detailed in Chapter 6, USS *Baya* (AGSS-318) was a World War II boat used extensively by both the electronics laboratory and the undersea center to test new sonar capability, even going to the extreme of major reconfiguration of the bow to do that. Bob Waldie was a principal investigator in those efforts. One of the first scientists drawn to the U.S. Navy Radio and Sound Laboratory/ University of California Division of War Research complex during World War II, Waldie remained after the war as an employee of the Navy Electronics Laboratory. Throughout the war and the early post-war period, his area of expertise was sonar. For a number of those years, he envisioned the substantial value of a modern submarine to test sonar and diving concepts.

A previous chapter highlighted the importance of 1960 as a year of remarkable achievements for the Point Loma laboratory. Not mentioned was approval by the Navy of the research submarine concept proposed by Waldie. The keel was laid for the sub, named USS *Dolphin,* in 1961, the first and only boat of its design, and construction began on what was originally planned as a short-lived test platform for collecting data.

The 1963 sinking of the state-of-the-art nuclear submarine USS *Thresher* (SSN-593), however, resulted in an abrupt halt to all submarine construction while

---

[106] NOSC *Outlook*, March 22, 1974, 3.

causes were investigated. Although conventionally powered (the last such U.S. submarine), *Dolphin* was included in the work stoppage. Three months before the loss of *Thresher*, Waldie and his associates had published two reports proposing the sonar suit design and the acoustic and oceanographic research programs for *Dolphin*.[107] The construction delay allowed the NEL team to reconsider and develop a comprehensive underwater test program. That planning greatly changed the future of the sub, which was initially intended to conduct sea trials relative to deep-diving and quieting techniques and then be scrapped. Instead, the electronics lab established a Dolphin Research Sonar Project Office in 1966 and began to formalize a detailed plan for operations of *Dolphin* following her scheduled commissioning in two years. (There was a minor hiccup almost exactly in the middle of that period, when Waldie and his team were transferred to the Naval Undersea Warfare Center. Their project office and their planning continued uninterrupted except for a few minor administrative hurdles.)

The extent of the difference in *Dolphin*'s planned usage was fairly obvious from the remarks of the keynote speaker when she was launched June 8, 1968, at the Portsmouth Naval Shipyard: "We look to *Dolphin* to patrol the unknown and answer questions about it… *Dolphin* will lead the way for the Navy's deep fleet of the 21st Century."[108]

According to John Benya, Point Loma lab engineer whose sole project throughout his long career was *Dolphin*, following initial sea trials, sound tests, and deep-water firing of a torpedo, the boat returned to the shipyard

> for conversion to the PHASE II configuration which removed the torpedo tube and installed the research sonar dome. That added 13 ft to the length of the boat (now 165 ft overall). This was required for the Gulf of Alaska and BQS-15 XN-1 sonar tests.[109]

After that shipyard period and transit of the Panama Canal, *Dolphin* arrived at the undersea center's pier for the first time November 7, 1970. The boat's crew had little time to reunite with loved ones, who had been transferred from the East Coast, before they were at sea again, headed far north for sonar exercises with USS *Baya* and an oceanographic research ship. The group spent four months in the Gulf

---

[107] R.L. Waldie, "Proposed Sonar Suit and Research Program for the Deep-Diving Submarine Dolphin (AGSS-555)," Navy Electronics Laboratory Letter Report 081, January 1963; and "Proposed Acoustic and Oceanographic Program for the Deep-Diving Submarine Dolphin (AGSS-555)," NEL Technical Memorandum 583, 14 January 1963.
[108] Dr. Robert A. Frosch, Assistant Secretary of the Navy for Research and Development.
[109] John Benya email to Tom LaPuzza, February 10, 2014.

of Alaska before returning to San Diego with definitive data providing the Navy a good understanding of the reliable acoustic path and how to make tactical use of it to benefit the submarine force.[110]

Dolphin's hull was an eighteen-foot-diameter cylinder with hemispherical end caps fashioned of HY80 steel. Displacing 925 tons submerged, the submarine seemingly wasn't much to talk about, but

> Highly automated, the boat had three computer-operated systems, including a hovering system, and a twelve-ton scientific payload to exploit deep-diving submarine technology and to pursue acoustic and oceanographic research at great depths. *Dolphin* was designed to carry more sonar per ton than any other sub in the world.[111]

Its other major claim to fame was that it was billed as the deepest diving submarine in the world, although diving depths were never revealed.

Given the planned focus for a scientific rather than a tactical mission, the boat's berthing included spaces not only for the crew of three officers and twenty-one enlisted personnel, but also three civilian scientists.

In addition to extensive evaluation of new-capability submarine sonar systems, *Dolphin* played a major role in evaluating Navy efforts, carried out by the Point Loma laboratory, to develop optical communications for submarines. Such communications were intended to decrease or eliminate any possibility of enemy interception of acoustic communications. *Dolphin* participated in evaluation of proposed laser communication systems in the mid-1970s and again in 1981,1984, and 1991.

Both NEL and NUC had experimented with various designs of a Mobile Submarine Simulator, basically a torpedo-shaped device that could be launched by a sub under attack from the surface and, if effective, lead the attackers to pursue it while the submarine escaped. In 1976, *Dolphin* successfully demonstrated the

---

[110] A fairly recent journal article (2009) provided this definition: "In the concept of a reliable acoustic path (RAP), a receiver placed at or below the critical depth can detect shallow sources out to moderate ranges independent of near-surface water conditions or bottom interaction (hence, the identification as a 'reliable' path)." Lisa M. Zurk, "Passive detection in deep water using the reliable acoustic path," *Journal of the Acoustical Society of America*, 125, 2576 (Abstract). Zurk's paper discussed "implications… on future Navy systems."

[111] Tom LaPuzza, "San Diego-based Research Submarines," *Mains'l Haul*, Vol. 50, 3 & 4, 69-70.

USS *Dolphin* (AGSS-555) steaming out of San Francisco Bay toward the Pacific.

first launch of an operational MOSS, "which subsequently became integral to defensive systems on all fleet ballistic missile and Trident submarines."[112]

John Benya explained a critical element of the boat's contributions to the submarine Navy:

> The Navy has a rule that all new equipment must be certified on a submarine before it can be installed on an operational boat. The cost of certification on a nuclear submarine is horrendous, but the cost for the same process on Dolphin is about ten percent of that. That's really where Dolphin paid off for certain systems, with the substantial cost savings to certify and allow new equipment use on operational submarines.[113]

Over a commissioned lifetime of almost four decades, USS *Dolphin* provided the Navy a substantial asset in significant technology improvement areas. A number of those will be discussed in more detail in Volume II, as will additional undersea vehicles and systems developed by the Point Loma laboratory.

[112] "Research Submarines," 70.
[113] John Benya, phone conversation with Tom LaPuzza, February 8, 2014.

BERKONE

The Navy's Man-in-the-Sea program, most visible component of which was SEALAB, lived up to its title: it put humans underwater for substantial periods of time to determine what sort of physiological and psychological implications that would have. As described in a previous chapter, long-term underwater living potentially provided a survival mechanism for several scenarios: an Extinction Level Event like the one that wiped out dinosaurs, or Armageddon, or, more reasonably, a preparatory step to establishing a lunar colony. SEALAB I and II contributed valuable data toward coping with one or several of those scenarios.

One critical factor for the Navy divers who participated in the effort was the need to live and work at high breathing-gas pressure levels for substantial time periods, and then the absolute requirement to decompress over suitable periods before returning to the one-atmosphere pressure of the surface world. Issues related to SEALAB I diver recovery and decompression resulted in development for SEALAB II of Personnel Transfer Capsules (PTCs) and a Deck Decompression Chamber (DDC) aboard a dedicated surface support craft. The latter was positioned aboard a staging vessel that previously had played an integral role in the Polaris missile "pop-up" testing. Fashioned of two barges 110 feet long and 34 feet wide, their connection by a covered center structure 22 feet long formed a U-shaped vessel. Already aboard were a galley, dining and storage facilities, electricity generators, air compressors and a fifty-ton-capacity crane. Added for SEALAB were a diver ready room and the DDC, which could support simultaneous housing and decompression facilities for ten divers for extended time periods. (SEALAB II divers spent fifteen days at a depth of 205 feet; their decompression period was thirty hours.)

The surface support craft was dubbed "*BERKONE*," in recognition of two Center individuals substantially involved in the effort (BERKich-mazzONE).

Joe Berkich was an optical technician in Pasadena who had no diving experience when he found himself unexpectedly working as an underwater photographer at the Center's San Clemente Island facility. He subsequently provided instrumentation photography of weapon firings of Polaris, the Anti-Submarine Rocket, and the Harpoon anti-ship missile.

He later participated in the CURV retrieval of a hydrogen bomb from the Mediterranean Sea. As a supervisory electronics technician, Berkich also managed a Marine Corps program developing a bazooka to fire infrared missiles and worked for a number of years on the Integrated Undersea Surveillance System (IUSS). On the latter, he spent time in the Azores with a NATO group recovering and repairing system cables and placing them back on the ocean floor. When he returned from Europe, he continued work on IUSS, traveling from Newfoundland to the Caribbean installing computer systems.

He retired in early 1990.[114]

Walt Mazzone was a retired Navy captain when he came to the Center in 1970. His lengthy career in uniform included eight World War II submarine patrols. After the war, he joined the new Medical Service Corps (MSC), serving six years with the Armed Services Medical Procurement Agency in New York.

Based on his involvement with MSC, he developed an interest in diving, specifically in studies of escape from submerged submarines (discussed earlier in this chapter). He was the first medical administrative officer to attend Navy Deep Sea Diving School, "and with Harrison Stahnke, inventor of the Stahnke Hood, he made the deepest open water escape from a U.S. sub—318 feet."[115]

After serving as project officer for SEALAB I and II, and diving officer for SEALAB III, he played instrumental roles in early Navy deep-sea diving experiments and helped establish the training facility for medical officers and hospital corpsman designated to serve on conventional and nuclear-powered submarines: "At one time every U.S. Navy submarine operating had a medical officer or a corpsman on board that I had helped train. I'm very proud of that."

Upon retirement from active duty, he went to work at the Naval Undersea Center, where he continued his underwater exploits as possibly the only individual qualified to pilot *Makakai*, *Deep View*, and NEMO. After serving as one of the principal operators of the Stable Semi-submerged Platform during sea trials, he contributed to undersea surveillance projects such as the Systems Validation Model and the Sound Surveillance System, and worked with Center marine mammals. His civilian retirement occurred in early 1980.

---

[114] NOSC *Outlook*, February 2, 1990. 5.
[115] NOSC *Outlook*, February 29, 1980, 4.

13

The Decade Between the Mergers

In 1967, the Navy restructured its two West Coast laboratories, adding small organizations to each but principally pulling away sizeable chunks of programs and people from both and molding them into a third lab. With some minor changes, that was allowed to stand for a decade, while personnel movements geographically consolidated most of two of those labs in San Diego on a five-mile-long peninsula bordering the western edge of the harbor. In 1977, the Navy consolidated them organizationally. This chapter and the next deal with the decade between, the important people and programs of those two organizations—the Naval Electronics Laboratory Center (NELC) and the Naval Undersea Center (NUC), and the initiation of the process by which they became one.

Recounting briefly: In the 1967 reorganization, the U.S. Navy Electronics Laboratory (NEL) was renamed the Naval Command Control Communications Laboratory Center (NCCCLC). In short order several smaller Navy organizations would be consolidated into NCCCLC, the unwelcome name of which would be changed to Naval Electronics Laboratory Center, also in short order. Out in the desert, the U.S. Naval Ordnance Test Station (NOTS) became the Naval Weapons Center (NWC), to which the Naval Ordnance Laboratory at Corona, California, was added. In return for those additions and new names, both organizations were required to give up something—NCCCLC/NELC lost a group of oceanographers and acousticians and a couple of unique facilities, NOTS/NWC its Pasadena Annex and smaller facilities at Morris Dam, Long Beach, and San Clemente Island. Those ceded entities would form a new California laboratory, the Naval Undersea Warfare Center (NUWC).[1] Headquartered initially in Pasadena, a year

[1] The title "Naval Undersea Warfare Center" appears in this volume with some detail in several chapters, with a few casual mentions elsewhere. In Volume II, that title will reappear, based on the Navy's major laboratory reorganization coincident with the Base Closure and Realignment Commission (BRAC) action in 1991. In that reorganization, the Navy established four warfare centers, one of which was Naval Undersea Warfare Center. The "new" NUWC would have substantial impact on the Point Loma Navy laboratory, as we shall discuss at the appropriate time.

later orders from Washington moved the headquarters function to San Diego, while leaving the majority of the workforce in Pasadena.

Based on the reorganization, and subsequent actions of the Navy Department, the Naval Weapons Center departs this history now. As noted earlier in this work, its story is being related in an excellent set of volumes titled "The History of the Navy at China Lake, California." (At the time of this writing [2020], four volumes had been published and the fifth was drafted and under review.)

As for the two San Diego-based Navy laboratories, management teams were constituted (or already in place), and they began developing practical methodologies to move into the future with more, or less, programs and people. Captain William Boehm and Dr. Ralph Christensen at the electronics laboratory focused on management changes and training to improve the performance of the organization, its various units, and individual employees. Among important changes was the fact the captain's title had been upgraded from "Commanding Officer and Director" to "Commander" with the July 1, 1967, establishment of the three West Coast laboratories. At the time, it had been almost two decades since the Chief of Naval Operations (CNO) had directed that the senior officer at NOTS and his counterparts at the two other Bureau of Ordnance laboratories be accorded the title (not the military rank) of commander. The Center's title was changed as well, "according to NELC Notice 5450"; it would be the Naval Electronics Laboratory Center for Command Control and Communications, although the last five words would somehow disappear, perhaps because the abbreviation of "NELCCCC" or "NELC4" would be prohibitive to common sense. It would be the following spring before the CNO directive changing the name officially.

Meanwhile, NUWC Technical Director Dr. William McLean, with substantial assistance from Doug Wilcox in Pasadena and Dr. Don Wilson in San Diego since he himself was still living in China Lake, began developing a set of technical departments, while the commander, Captain Grady Lowe, spent large amounts of time shuttling back and forth among China Lake, Pasadena, and San Diego as he commanded both NUWC and NWC for several months.

Naval Electronics Laboratory Center

Close on the heels of the reorganization, the electronics lab's newspaper

Calendar provided several statements of assigned tasking. The July 14 issue offered: "NCCCLC will serve as a center of excellence in the fields of radio, radar, digital data links, satellite communications, electronic warfare, tactical and strategic data systems, and electronic displays."[2] There was strong emphasis on fundamental and applied research in those areas, according to the article, which resonated well with Dr. Christensen's philosophy on Navy labs. He was perhaps less interested in the expansion into other areas that included "detailed engineering design to achieve unified systems integration for command support functions."

A week later, in the article advising about the laboratory name change, the formal mission was provided: "To conduct a program of warfare analysis, research, development, test, evaluation, systems integration and fleet engineering support in command control and communications technology."

Planning began to develop or identify a management philosophy to pursue assigned mission responsibilities effectively, plus an equally effective organizational construct to support that. In early 1968, coincident with the start of the Managerial Grid training (in fact less than two weeks after the initial training session began; see Chapter 10), laboratory leadership announced a major reorganization:[3] the two "laboratories" that formed the foundation of previous technical program work—Electronics Technology and Data Systems and Evaluation—were replaced by three: Research, Electromagnetics Technology, and Command Control Technology, in order to increase the Center's ability to perform its new mission "emphasizing Command Control and Communications." Following completion of a little more than a year of the grid training, reported as having a positive effect on Center management, the two top managers who had led that effort departed within a few months of each other. Dr. Christensen retired at the end of April 1969, and Captain Boehm was relieved on June 24 and transferred to the Naval Electronic Systems Command, Southwest Division, which, as mentioned in a previous chapter, would become part of the Point Loma Navy laboratory in about three decades.

Christensen's replacement was Dr. Clarence Bergman, an electronics engineer who had worked as a contract manager on the Minuteman III Intercontinental Ballistic Missile and supervised development of data processing

---

[2] U.S. Navy Electronics Laboratory [sic] *Calendar*, July 14, 1967, 1. The newspaper's banner and masthead remained unchanged for several issues after the reorganization and name change.

[3] Naval Electronics Laboratory Center (NELC) *Calendar*, March 22, 1968, 2.

equipment for the Air Force, which suited him nicely for the many NELC projects requiring advanced computing capabilities. The new commander was Captain Mabry D. Van Orden. The captain had been assigned previously as a junior officer to NEL on the Omega program at the start of the decade. In fact, he appeared on the front page of the first *Calendar* featuring photos: March 25, 1960.

In relatively short order, the new management team seemingly reversed the 1968 reorganization, as the recently separated research component was integrated back into the Electromagnetics Technology Laboratory and Command Control Technology Laboratory. *Calendar* reported, "It was stressed that the closer linking of research with the principal programs of the Center would provide for greater effectiveness of the research now underway."[4]

Within a few months' period in spring-early summer 1969, Dr. Clarence E. Bergman (l) became NELC technical director, and Captain M.D. Van Orden relieved as the laboratory center's new commander.

[4] "Dr. Bergman Describes Efforts To Link Research, Technology," NELC *Calendar*, November 7, 1969, 1.

An interesting juxtaposition occurs in that issue, as the "linking" of research and technology article appears on the front page immediately below an article announcing the retirement of Dr. T.J. Keary, whom Dr. Christensen had selected to head the research effort nineteen months earlier. Whether Dr. Keary's announcement of upcoming retirement influenced the linking decision, or that decision motivated his retirement, is unknown, although the pairing of research with the technology development substantially affected by it appears a reasonably pre-emptive management decision.

At year's end, NELC held an open house for employees' families; a special eight-page *Calendar* published several days before included an invitation to the event and summarized the 1967 reorganization, in which "greater management responsibilities were placed on the Navy's laboratory centers through all phases of research and development."[5] The issue included a general technology report covering satellite communications, radar, command control and navigation systems, and microelectronics. Individual articles reported on lab support of the Apollo 11 visit to the moon, liquid lasers, and an entire page on vision research.

There were also articles on GARD and CATS. (Interestingly, the undersea warfare center also had a feline-oriented program acronym, representing a weapon: the Cable Assisted Torpedo System.) The General Address Reading Device was NELC's contribution to reducing the message traffic workload aboard the Navy's smaller ships. Typically, the message traffic was printed out by teletype in its entirety, even though only a small percentage held interest or importance to a specific ship, particularly to a frigate or a destroyer escort. In fact, "as few as one message in ten sent by Fleet Broadcast may be of interest to a given ship," according to problem manager Bob Rios.[6] GARD allowed each ship to develop and maintain a list of message addresses of importance, which it then compared to Fleet Broadcast message traffic. It printed the addresses of all messages, but only the entire text of those messages ship's force had designated of interest. Follow-on efforts replaced the GARD core memory with a Large-Scale Integration (LSI) solid-state memory and replaced a number of low-speed teletypewriters with a

[5] NELC *Calendar*, December 19, 1969, 3.

[6] The reader is reminded that Navy laboratory terminology since before World War II had employed the term "problem" for what later would be termed a "project," with formal numbering schemes for "problems" assigned by the Navy bureaus and later the systems commands.

single, quiet, high-speed teleprinter.[7] According to a newspaper report on the effort,

> A core memory is a ferro-magnetic device consisting of many small individually and collectively wired donut-shaped magnets. A solid-state LSI memory implemented in a silicon chip eliminates much complicated backplane wiring and takes up a fraction of the space required by a core memory.[8]

The Centralized Automatic Test System (CATS) automatically monitored the performance of shipboard systems, initially radar, communication, and evaporator systems. If it proved successful in reducing the requirement for human monitoring, plans were to extend it to electronic warfare and navigation systems, and even ship damage control, electrical power, and propulsion systems.

And yet another reorganization

The ink was hardly dry on the research-technology reorganization statement before another was announced, affecting the fundamental structure of NELC. The two (then three, then two again) "laboratories" were replaced with six departments: Command Control and Communications Programs, Electronics Technology, Information Technology, Engineering Sciences, Computer Sciences, and Support.

The second *Calendar* issue of the year introduced the reorganization with a story providing half a dozen reasons for it, each in a paragraph. Captain Van Orden, in a column on the second page, jammed them into a single sentence, the effect of which was to give some sense of the intensity and urgency of the situation:

> The drastic cuts in Navy forces and funds, the necessary reorientation of the research program, the recommendations of the Grid critiques, the approval and adoption of the [Grid] Phase Four policies and ideals, the arrival of programs and people from NASL and Corona, the NIF conversion, the changes in top management personnel—all of these required a more rapid adaptation than had been anticipated.[9]

---

[7] "Multiplex GARD deploys for Med," NELC *Calendar*, July 2, 1971, 1.
[8] "LSI memory tested successfully in GARD," NELC *Calendar*, February 12, 1971, 1. Interesting comparison between the two provided in a sidebar: core memory cycle time of 1.8 microseconds and access time 750 nanoseconds, total volume 488 cubic inches, weight twenty pounds. For LSI memory cycle/access times of 600 and 400 nanoseconds; total volume 48 cubic inches; weight two pounds.
[9] Captain M.D. Van Orden, "Commander's Comments," NELC *Calendar*, January 16, 1970, 2.

The comment about the Grid bears brief explanation, since the intent of that training, as detailed in Chapter 10, was "to define leadership behavior patterns that can produce organizational excellence." Hundreds of employees had received initial or follow-up training, and it appeared to be working, based on a statement in the front-page article:

> **Managerial Grid training** [emphasis in original] has fostered a new management style with two-way communication, teamwork and increased mobility within the Center as goals. At Grid critiques, participants leveled criticism at a system that discouraged cooperation between divisions and kept individuals and groups in isolated boxes. Participants pointed to the need for a system that offered capable persons opportunities for personal development, advancement and increased responsibility.

Perhaps without intentionally meaning it, one might suggest that statement in the reorganization article translated to: You wanted change; now you've got it.

In his column, Captain Van Orden noted several intended outcomes of the reorganization. First, he wrote, the Center had to meet the demands of the operational Navy as it adapted to fast-changing technology. Second, the restructuring simplified the formal structure of NELC and allowed operating managers to exercise their authority, and meet their responsibilities, in a more decentralized way. Finally, restructuring was designed to give greater opportunity for the most high-achieving managers and technical staff to advance.[10]

The year (1970) was also important in that it saw a significant change in the top tier of management. Historically, the lab had been managed by a naval officer, usually a captain, who was listed as "commanding officer and director." When Dr. Maurice Halstead was presented the first laboratory-level award in 1961, it was the Commanding Officer and Director's Special Annual Honorary Award for Scientific Achievement. Although the technical director, Ralph Christensen, was on hand, his title was not part of the award. That all changed in 1970:

> A new joint chief executive, consisting of the Center Commander and the Technical Director, ensures close coordination of technical programs with total Center operations. A Chief Staff Officer and a Deputy Technical Director, who is selected from the heads of the major technical

---

[10] During his first year in command, Captain Van Orden contributed a number of those columns to the newspaper, providing timely information to employees on matters of significance. His first column appeared in the issue (July 3, 1969) immediately after he'd assumed command, introducing himself and some thoughts on management and, interestingly based on the subject of this section, promising a period of stability and relative calm at the Center. In the next issue he addressed the Managerial Grid, training for which was imminent.

departments on a rotating basis (12-18-month assignment), provide assistance to the joint chief executive.[11]

In October, the technical director reported the reorganization and attendant management initiatives were working, but there was still a lot to be done. He advised specifically on three topics, namely that communications ("up and down") seemed to be working well, better planning was needed across the board, and attitude was important: "We need people who don't turn off at 4 p.m., who think creatively about problems while driving, at home, etc."[12] It was remarkably reminiscent of the China Lake philosophy that migrated to Hawaii.

"25th" Anniversary celebrated

As 1970 ended, NELC prepared to celebrate not only the holiday season, but its 25th Anniversary (continuing to disregard the five years of the Navy Radio and Sound Laboratory as part of its heritage). A commemorative *Calendar* issue featured a proclamation from the mayor of San Diego and congratulatory messages from the Navy brass (the Secretary, the Chief of Naval Operations, Chief of Naval Material, and Director of Navy Labs) and from several former commanding officers. It also published summaries and photos of important technical accomplishments, a two-page spread on microelectronics work, and a list of more than seventy-five plank owners (calculated from 1945).

The commander and technical director provided a two-column article in which they "reflect on past, look ahead." Among other things, they wrote,

> Since 1945, when the Navy Radio and Sound Laboratory and the University of California Division of War Research joined to become NEL, this Center has devoted its resources to the development of electronic systems and equipments to improve the effectiveness of the United States Navy.[13]

As detailed in Chapter 5, that wasn't an entirely accurate statement. In actuality, shortly after the war NRSL was renamed NEL. UCDWR, a contracted organization which reported to the Office of Scientific Research and Development,

---

[11] NELC Annual Report 1970, 5.
[12] "Dr. Bergman cites Center's progress, outlines challenges ahead," NELC *Calendar*, October 23, 1970, 1.
[13] NELC *Calendar*, December 4, 1970, 2.

continued to operate and work on its "completion report" until June 30, 1946, when it was disestablished by OSRD. Over that period its programs were either terminated or turned over to the Point Loma Navy laboratory. Of the hundreds of UCDWR employees, some returned to the university (i.e., UCLA), such as Leo Delsasso and Vern Knudsen; a number sought and were provided employment at NEL/NELC; a few under Carl Eckart formed the Marine Physical Laboratory (and later came to the Navy lab, such as Dr. Robert W. Young); and others went their separate ways.

Dr. Bergman's statement that management initiatives were going well faced a hiccup, although a positive one, as for only the third time in this Navy organization's complex and combined history the commander would be selected for flag rank during his tour at the lab. (The other two were P.D. Stroop at the Naval Ordnance Test Station China Lake, and Tim Flynn at Space and Naval Warfare Systems Center San Diego). In late February 1971, Captain Van Orden was notified he would be putting on his first star, which he did at the ceremony when he was relieved of by Captain Norton D. Harding on January 14, 1972. Rear Admiral Van Orden read his orders, which included reporting to his new position in the Office of the Chief of Naval Operations, directing an action team to improve naval communications. He would later serve as Chief of Naval Research.

Management By Objectives

Harding, who came to NELC following tours at Naval Electronic Systems Command as director of research and technology and then as special assistant to the NAVELEX vice commander, had worked closely with Center personnel during their development of the Message Processing and Data System for USS *Nimitz* (CVN-68). When he arrived as the Center commander, he joined Dr. Bergman, the other half of the "joint chief executive," in his strategic planning efforts, himself instituting a structured program of Management By Objectives (MBO) in early 1974.[14] Described by management thinker Peter Drucker in the 1950s and later developed by his student George Odiorne, MBO was meant to counter what Drucker called "the activity trap," the tendency of managers to concentrate so fully on the immediate task that they lost sight of the long-term

[14] NELC *Calendar*, December 21, 1973.

work objective. By focusing on ultimate objectives, MBO was intended to liberate managers and employees from non-creative routine or rigid work methods. It encouraged creative, efficient work processes, and personal accountability.[15]

The MBO philosophy featured a hierarchy of "stuff" to achieve, listed in descending order of precedence as "goals, objectives, strategies, and tactics." In the January 18, 1974 *Calendar* (and continued in the next issue), Captain Harding answered, at some length, a set of questions about the philosophy now guiding Center management, stating, "NELC's Primary Goal as currently stated, is a rewording of our mission statement as given to us by the Chief of Naval Operations. Our Primary Goal is to carry out the mission assigned to us by the CNO."

The objectives formulated by Center management to achieve that goal (i.e., the mission) were as follows:

-

Expand the NELC RDT&E program scope to fulfill charter responsibilities

Establish and maintain a balanced Center staff

Establish and maintain a balanced distribution of funding sources

Establish and maintain a balanced technical program

Improve the effectiveness of NELC managerial, technical, and administrative procedures[16]

These objectives, explained Captain Harding, were interconnected:

> Our ability to carry out our technical program… is contingent upon how well we can do marketing with Washington sponsors both for technical program objectives and for funding source objectives … our ability to go forward with significant new facilities is constrained by how well we convince our bosses in the military construction appropriation circuit that we need significant new facilities.[17]

(Apparently Center personnel were successful in convincing their bosses about facilities requirements. The front page of the same issue in which Harding

---

[15] "Management by Objectives," *The Economist*, October 21, 2009. Adapted from *The Economist Guide to Management Ideas and Gurus* by Tim Hindle (London: Profile Books, 2008).
[16] NELC Annual Report FY1973, 7.
[17] *Calendar*, February 1, 1974.

initiated his discussion of MBO announced the president had signed the 1974 Military Construction bill, which included $3.5 million for the first increment of the NELC Electronic Development And Test Laboratory.)

Higher-level happenings

Fairly coincidental with the Van Orden-Harding change-of-command on the West Coast, another at a much higher level was occurring on the East Coast, as Admiral Isaac C. Kidd, Jr., relieved Admiral Jackson D. Arnold as Chief of Naval Material (CNM). Kidd's brief but pointed message in his remarks included his concern that "We are in a deadly serious race, my friends, a race wherein our competitor is in an almighty rush to acquire a naval capability of the first magnitude." Judging the reason, he said, was not his concern or that of the people in his new command, but he insisted it was "our absolute obligation to ensure that we maintain our naval superiority…"[18]

(The father of the new CNM, by the way, Rear Admiral Isaac C. Kidd, Sr., died at Pearl Harbor just twelve days before his son graduated from the Naval Academy. For his discharge of duty during the battle, personally directing action against attacking forces on the deck of his flagship, USS *Arizona* (BB-39), until it blew up, he was posthumously awarded the Medal of Honor. As the son received his commission less than two weeks later, a tremendous cheer erupted in the audience in tribute to the father, an emotional response unprecedented in the history of Annapolis commissioning ceremonies.)

As CNM, Admiral Kidd was responsible for the Navy's laboratories, including NELC. The Center's Public Affairs Officer, Joel Meriwether,[19] interviewed Admiral Kidd in Washington, gathering these important messages for Center management and personnel:

---

[18] Admiral I.C. Kidd, Jr., change-of-command remarks, December 1, 1971, quoted from NELC *Calendar*, January 14, 1972, 3.

[19] Meriwether, the second NEL/NELC PAO and the first for the Naval Ocean Systems Center, served in that position from 1968 to 1988. He established a successful public affairs program for the first decade of the combined electronic and weapons organization, and was rewarded with the Center's highest honor, the Lauritsen-Bennett Award. See Naval Ocean Systems Center *Outlook*, July 8, 1988, 1.

> I asked NELC if it could spare some gentlemen to go to the Mediterranean when I was sent there. This NELC did. And those gentlemen who went ended up being not only among my very closest friends, but most important advisors… By George, I don't think we've brought any significant program in under the target price since John Paul Jones… in some of the mistakes that we make, you really have to put in a whole career to botch it up with the degree of thoroughness and efficacy with which we manage to do it without half trying.[20]

(While his disparagement of Navy R&D held substantial truth, he perhaps neglected, or forgot, the Polaris program, to which both NELC and the undersea center had contributed significantly, and its completion *five years* ahead of schedule, and thus, almost certainly, "under the target price.")

Asked about projected shore establishment cutbacks and the possibility they would "cut deeply into R&D activities," he responded,

> Yes, probably. I don't think there are going to be any sacred cows… I don't know if they will all be cut the same amount. There are some areas where we are obviously weaker than others, such as ASW and electronics. I think the wars of the future will be won by the fellow that controls the electronic environment. I am painfully aware that electronics R&D should be one of the last areas to be cut… The reassuring thing to me is our own laboratory people are making the recommendations of what to cut out, because I'm sure not that smart.

What was not mentioned, perhaps because it had not surfaced yet, was the slogan (battle cry?) he used repeatedly—and had printed on posters—to portray his demand that the systems commands and the Navy laboratories strive to provide the best technologies to the warfighter, in an expeditious and cost-effective manner: "What have you done for the Fleet today?"

Support of the fleet

As related earlier, both the electronics and weapons laboratories had volunteered a number of technical personnel to leave the relative calm and safety of California to spend months in war zones to apply their expertise to the solution of immediate and short-term problems facing the warfighters in Vietnam. An early example of NELC fleet support, however, occurred not in-country, but aboard ship, specifically a capital ship: USS *New Jersey* (BB-62) had served in World War II and the Korean War, providing shore bombardment support of amphibious

[20] NELC *Calendar*, September 1, 1972, 1.

Dr. Robert C. Kolb (right) and Lieutenant Commander (and also Dr.) Floyd Hollister rode USS *New Jersey* from Long Beach to Hawaii, programming (and in fact learning to program) their Initial Ballistic Correction System on the way.

landings. Mothballed for a period, she was recommissioned for service in the Vietnam War, now fitted with missiles, but still assigned shore bombardment as a significant mission. For this tour, her commanding officer had issues with the manual method still in place to calculate ballistic and navigation data, particularly with the time the calculations required and the potential for human error.[21] Two young electronics laboratory Ph.D.s, Lieutenant Commander Floyd Hollister and Robert C. Kolb, were assigned to the ship under the Vietnam Laboratory Assistance Program, to procure, program, and install a digital computer system to improve targeting. They also were responsible for providing appropriate training of the crew in its use.

Lieutenant Commander Hollister had ridden the ship from the East Coast through the Panama Canal to the Long Beach Naval Shipyard. Although there were no firings of the sixteen-inch guns during the voyage, he was able to gain a basic understanding of the captain's concerns and desires for improvement to the firing sequence.

After installing the equipment—formally titled Initial Ballistic Correction System—aboard *New Jersey* at the shipyard, the naval officer and the civilian rode

[21] "Computer-centered systems provide USS NEW JERSEY with ballistic and navigation data," NELC Command History, 16 Oct 1968, 5.

the ship to Hawaii, programming along the way:

> … it was assembly-language programming, no compilers, just an assembler… both Floyd and I learned how to do the assembly language while sailing to Hawaii… The result was that it worked well in Vietnam. Captain Snyder was pleased and wrote some strong endorsements for the work. [He] claimed it improved the effectiveness of their weapons and so I think it was a very successful effort.[22]

As will be discussed in Volume II, Kolb went on to head the Command and Control Department and later to serve as Center executive director 1996-2003.

Later, as Admiral Kidd had remarked gratefully in his interview with PAO Joel Meriwether, NELC had sent several of its top technologists to support him when he was designated as Commander, Sixth Fleet. One of the engineers sent to the Med at the admiral's request was Carl Erickson. Two months before the Kidd-Meriwether interview was published, in a regularly featured *Calendar* column titled "Viewpoint," he had discussed his tour as Navy Science Assistance Program (NSAP) science advisor with Sixth Fleet.[23] He quoted from a memo he had sent several months earlier to the fleet commander who had relieved Kidd:

> To date, the doors to the Laboratory community have been opened a crack to the needs and the purpose of the SIXTHFLT, but the benefits of this year are actually mine, not yours, as I have learned much. I am now convinced that what Dr. Joel Lawson [Director of Navy Laboratories] has been preaching for a long while is correct. 'Live it, then bring the knowledge of how it really is, back to the Laboratory community.'

Among Admiral Kidd's many initiatives when he was Chief of Naval Material, prior to the Sixth Fleet assignment, was one to do exactly that: allow Navy civilians to "live it." The CNM Face to the Fleet Cruise Program was intended to get laboratory technical personnel out on the ships for which they were developing technology, in hopes of promoting better understanding on both sides. Interestingly, in a time period when that was still rare, it was a gender-neutral program, and the first woman to participate was an NELC operations research analyst, Ann Davis.[24] Davis spent three days and two nights on the carrier USS *Ticonderoga* (CVS-14) during a training exercise in southern California waters.

---

[22] Dr. Robert C. Kolb SSC Pacific oral history interview conducted by Tom LaPuzza, October 18, 2012, 14-15.

[23] NELC *Calendar*, July 21, 1972, 2. In addition to that effort, Erickson had served five assignments in Vietnam under the NSAP-predecessor Vietnam Laboratory Assistance Program.

[24] "Ann Davis is first woman on CNM Face to Fleet Cruise," *Calendar*, November 10, 1972, 1.

Responsible for interface definition between shore-based and sea-going command control systems, she commented after her shipboard stay that she

> really learned a great deal in a short period of time. It always helps to have had experience in the actual environment for which you are designing systems. I now have a feeling for what it is like to work on board ship where space is limited and men and equipment must function in cramped quarters.

Chuck Manning

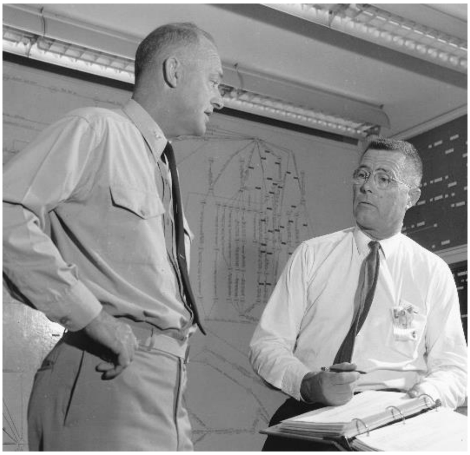
In an interesting juxtaposition, the same front page that featured the bright young systems analyst a few years into her NELC career also reported on a somewhat older NELC physicist who was concluding his, calling himself to task for the fun of it: "It's almost a sin for any one man to enjoy his work as much as I have enjoyed the past 30 years at NELC," said Charles S. "Chuck" Manning. "I can see no reason not to let somebody else have the fun now." Manning arrived on Point Loma in mid-1942 as a high school physics teacher, hired to work as a civilian employee for the University of California Division of War Research. Instead, he spent the years 1943 through 1946 as a Navy Reserve lieutenant, also assigned to UCDWR. When the war ended, he became a civilian again, hired as a branch head for the brand-new U.S. Navy Electronics Laboratory.

Throughout those various reorganizations detailed above, from two "laboratories" to three to two and then to six departments, Manning was usually heading one of them, the one concerned with the organization's primary focus of command and control. He served as NELC's first deputy technical director, beginning in 1970, considering it a "key and essential" position managing day-to-day details, freeing the TD to "function as an outside salesman for the Center."

The following year he moved to Naples and joined Admiral Kidd as technical representative to Sixth Fleet and ASW Forces Mediterranean (and he was almost certainly one of those "gentlemen who… ended up being not only among my very closest friends, but most important advisors").[25] That tour reinforced Manning's already solid belief that NELC's primary responsibility was to serve the fleet. His most significant contribution to that fleet and to the lab was his leadership of major programs—GARD and MPDS, discussed above and below, respectively; the

[25] NELC *Calendar*, September 24, 1971.

Naval Electronic Warfare Simulator (see Chapter 6), which he conceived and on which he directed development; and the Naval Tactical Data System (Chapters 6 and 8). For his substantial effort at automating Navy information processing and display, he received the service's second highest award, the Navy Superior Civilian Service Award, in 1970.



NEL Commanding Officer and Director Captain H.C. Mason (left) and C.S. Manning discuss command and control technology.

Others served as well

This volume has detailed on several occasions the substantial efforts of both NEL/NELC and NUWC/NURDC/NUC personnel in serving the fleet directly and personally through VLAP and its successor NSAP. Those cited (so far) have been men. Before the participation of women in the formal fleet support programs, which will be discussed at the appropriate time, several women at both labs also left "the relative calm and safety of California" to serve.

Mary Bailey, a staffing clerk in the electronics lab's Personnel Office, served three volunteer tours in Vietnam, including at the beginning and at the conclusion. In a 1973 interview, she explained: "I was in Vietnam when American occupation first began and I wanted to be there when it ended. The government needed people and I wanted to contribute."[26]

Bailey worked in the Top Secret Control Office, part of the Military

[26] NELC *Calendar*, July 20, 1973, 2.

Assistance Command, Vietnam, in Saigon. Also employed there was fellow NELC employee Beverley Watkins, whose regular job was secretary for the Electromagnetic Systems Department. Among other things, she viewed it as an opportunity for foreign travel she had not yet experienced. Although the two lived in Saigon hotels, which provided a more comfortable environment than was usual at the time in-country, they still had to deal with shortages of facial tissues and coffee and with "wall-to-wall people" and "ridiculous" traffic requiring forty-five minutes for the four-mile bus ride to the office. There they worked long hours, six days a week. Replacing military personnel needed elsewhere, the women were assigned to tasks lasting four to six months.

Kathy Garoutte, a clerical employee in the Naval Undersea Center Personnel Office and later the Public Affairs Office, spent two months in Saigon as well, working in the Personnel Administration Control Group at the Defense Attaché Office there. She helped process the large number of incoming Permanent Change of Station military personnel, and trained Vietnamese employees to take over the task when she departed. She also noted challenges: Saigon was "'a city of many odors'… the combination of an archaic sewage system and a pronounced air pollution problem made breathing a rather unpleasant experience."[27]

Computer technology acquisition

Chapter 10 described "mechanization procedures" and the full-fledged entry of NEL into the computer age. Far bigger things were yet to come: NELC acquired an IBM 360/65 Third Generation computer system in 1969.[28] This was the revolutionary system on which IBM Chairman Thomas Watson, Jr., had bet the company, spending $5 billion when IBM's yearly revenue was $2.5 billion.[29] The 360 was the first widely available computing platform that could be adapted and extended and whose power could increase over time. Its memory could hold eight megabytes of core storage—sixty times the capacity of the previous IBM models.

[27] NUC *Seascope*, July 20, 1973, 4. And yes, coincidentally, with no cooperative contact and no known forcing function, both newspapers ran the articles on the same date.
[28] *Calendar*, February 14, 1969.
[29] Computer History Museum online, http://www.computerhistory.org/revolution/mainframe-computers/7/161 accessed June 28, 2015.

And it was modular, with prices for mainframe systems ranging from $1 million to $42 million, with monthly fees ranging from $20,000 to $800,000.[30]

NEL/NELC employees planned for forty-two months prior to signing a contract for the 360/65, which promised to be ten times faster than previous computer generations, enable twenty-seven sites for computing in the laboratory, and handle calculations of previously insurmountable complexity. With such power, laboratory personnel could work across the spectrum of electronic systems.

One use of such power was development and testing of software for use on ships. Seaborne computers could not be as complex or robust (or room-filling) as the IBM 360 system, but the Navy needed computing power at sea. NELC used the identical systems built for ships to test programs, write applications, and train operators. In August 1971, the Center acquired an AN/UYK-7 "ruggedized" multiprocessor computer designed for military applications. The UNIVAC AN/UYK-7 was five to twenty times more powerful than the system it replaced, and occupied one-fourth the volume of its predecessor system.[31] It was destined for use in the Navy's new Aegis shipboard fire control system.[32] NELC engineers and technicians were tasked with solving a variety of real-world challenges with the new platform. Allan Beutel, director of the Computer Sciences Department, pointed out that, while other laboratories and DoD agencies had AN/UYK-7 systems, they were all dedicated to specific projects. Only NELC's system was used for multiple projects and modular software developmental work.[33]

NELC technical programs

The effort to manage technology development effectively and efficiently was a crucial component of the NELC environment during the early to mid-1970s. And

---

[30] IBM Archives, http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_PR360.html accessed June 28, 2015. Prices in 2015 dollars based on U.S. Department of Labor CPI Calculator.

[31] David L. Boslaugh, *When Computers Went to Sea: The Digitization of the United States Navy* (Los Alamitos, California: IEEE Computer Society, 1999), 361.

[32] George Gray, "Sperry Rand Military Computers 1957-1975," *Unisys History Newsletter*, Volume 3, Number 4, August 1999.

[33] *Calendar*, August 13, 1971.

while the management philosophy espousing avoidance of the "activity trap" was substantially important to—you guessed it—management, the technical development work continued in a fairly normal fashion, with program/project teams working their individual efforts to place their individual hardware and software aboard ships. As a result of those efforts, a significant number of those programs and projects recorded important achievements during this period.

Among the ongoing programs, one of the most important was the Message Processing and Distribution System (MPDS). The fruits of NELC engineers' labor on the retired carrier *Bunker Hill* were evident as the USS *Nimitz* MPDS was delivered to the shipyard in 1972 for installation, and work began immediately on an identical system for USS *Eisenhower* (CVN-69). While that was underway, *Nimitz* was also underway at sea, and in the spring of 1974 processed its first official message traffic using MPDS.[34]

The Center's work in command and control technology development on the Anti-Submarine Warfare Ship Command Control System for USS *Wasp* (CV-18) resulted in follow-on leadership roles for more complex ASW command control capabilities.[35] One of those, the ASW Centers Command Control System, supported the Navy Worldwide Command Support System,

> serving the ASW Force Commanders and their Area and Sector Commanders. By replacing the various ADP equipment presently in use with an integrated system of computers and communication terminals, it will enable the ASW Force Commander to make and communicate near real-time decisions.[36]

It employed secure voice communication channels and dedicated digital links to form "a worldwide network of third-generation, shore-based, dedicated data

[34] *Calendar*, May 24, 1974, 3.
[35] NEL/NELC 1960s written sources—reports, newspaper articles, phone directories—invariably used the term "command and control." In later years of the same decade, it became "command control." And in 1979 it became "command and control" again. Based on the NELC technical document, *Wasp* received the ASWSC&C System. Documentation half a decade later rendered it ASWSCCS. Dr. Robert Kolb, who later headed the Point Loma lab's Command and Control Department, supervised the Tactical Command Control Division in 1978, and the Tactical Command and Control Division the following year. Asked about the confusion, he responded, "Over my career the terms Command Control and Command and Control were often used interchangeably. In my view they mean the same thing. Navy leadership sometimes expressed a STRONG [emphasis in original] preference which is why the center terminology changed in some cases." Dr. Kolb email to Tom LaPuzza, February 11, 2019.
[36] NELC Annual Report FY1973, Vol. II: Technical Summary, 9.

processing systems capable of exercising close control of fleet ASW forces on a near real-time basis."

Ocean Surveillance Information System

In 1970, NELC was designated as the lead laboratory for the highly classified Ocean Surveillance Information System (OSIS), which provided "timely and complete ocean surveillance information to the Fleet and to National Command Authority."[37] As discussed in several previous chapters, the Navy during this time period required a Technical Development Plan for all major programs. NELC completed one for OSIS, which was approved in April 1971. Based on preliminary studies by the electronics lab on sensors and information sources, the current capabilities and thus deficiencies,[38] the plan provided a framework for developing an improved capability to accept data on vessels operating at sea from all sources and to display that data and disseminate it, properly formatted, to designated users of the system. Plans included installation at the major commands in the Atlantic in 1973 and their counterparts in the Pacific two years later. A program redirection that required use of Worldwide Military Command Control System computers necessitated redesign of the OSIS software, which slightly delayed the installations.

A program that would have much greater impact on the fleet was initiated in early 1973 with a brief newspaper story headlined, "Center-wide involvement seen for new TFCC project."[39] Over the next decade, this effort to provide a dedicated shipboard space aboard aircraft carriers for battle group commanders, titled Tactical Flag Command Center, would indeed involve large numbers of Center personnel, resulting in successful Technical and Operational Evaluations in 1984.

Submarine communications

An inescapable reality of major programs developed at Navy laboratories—electronics, weapons, communications—is that they continue for multiple years,

---

[37] NELC Annual Report FY1973, Vol. II: Technical Summary, 9.
[38] NELC Annual Report for Fiscal Year 1970, Technical Document 100.
[39] NELC *Calendar*, February 13, 1973, 1.

often decades. As a result, reporting in a reasonable fashion on such developments requires selection of a specific, significant milestone—Operational Evaluation, introduction to the fleet—and discussing project work years before and after in relation to that specific time frame. Thus, the NELC work on submarine communications, mentioned casually in Chapter 10, is detailed here for that reason.

There have been several instances in this volume of reporting on the essential differences between diesel-electric and nuclear submarines. In fact, Waldo Lyon, who arguably knew as much on the subject as anyone at the Point Loma laboratory, went so far as to claim the latter were truly submarines and the former were merely surface ships that dove sometimes. Interestingly, two of the most essential aspects of operations related to submarines—detection and communication—were critically affected, negatively and positively, by that difference. The requirement to surface at regular intervals to charge batteries vastly increased the possibility of detection, and yet as markedly simplified communications. Detection probability dropped precipitately for a boat that remained submerged throughout a months' long patrol, but rendered communications difficult if not impossible.

Based on its long history studying the science of underwater acoustics, NELC was in a particularly advantageous position to develop the communication capability for a nuclear submarine force which spent little or no time on the surface.

The leader of that effort was Richard "Dick" Eastman, a San Diego State graduate with bachelor's and master's degrees in electronic engineering. During a three-year assistant professorship at State, he worked part-time for NEL on a pulse coded multiplex communication system. He started full-time at the lab in 1960. Among other assignments, he served as acting head of the Communications Techniques Division for about a year before establishing in 1967 the Fleet Ballistic Missile (FBM) Submarine Communications Program Office, later the Submarine Systems Programs Office. It was the lab's first program office. Under Eastman's leadership, it grew from three employees to thirty-eight (plus more than 125 other lab personnel who were tasked by his office), with initial funding of $250,000 that increased to more than $13 million in a decade.[40]

The office was "largely responsible for the development of the

[40] "Richard Eastman receives Navy Superior Civilian Service Award," Naval Ocean Systems Center *Outlook*, April 22, 1977, 1.

POLARIS/POSEIDON [sic] Command Control and Communications Systems," according to a newspaper article published on the occasion of Eastman's passing in 1978.[41] A major product of that effort was the Verdin Low Frequency/Very Low Frequency (LF/VLF) Communication System. (Verdin was not an acronym, but the name of a desert bird. Perceived connection between the two is unknown.) Providing up to four information channels for submerged FBM submarines, "It included a fixed shore-based and airborne transmitting system, a processing system and an automated control system, and provided an automated worldwide broadcast system."[42]

After feasibility tests in the early 1960s, Operational Evaluation (OPEVAL) was conducted in 1968 for the engineering prototype of what formally was known as the AN/URC-62 VLF/LF Communication System. As noted below, the computer-controlled, multichannel submarine broadcast system went into operation in late 1976.[43]

Eastman's "extraordinary management efforts" in establishing and stimulating the growth of that office, which significantly advanced the capability of FBM submarine communications, earned him the NELC Honorary Award for Achievement in Management in 1972.[44] The *Calendar* article reporting on his award noted that the management practices he had developed for his office were "very helpful" during NELC's spring 1972 reorganization, important aspects of which were "largely patterned" after his forward-thinking managerial concepts.

The following year, Navy officials recognized a shortcoming for the submarine force in the necessary connecting of Verdin and an essential companion system. The Submarine Satellite Information Exchange System (SSIXS) provided communications and data from world-wide sources to be downloaded to Verdin equipment for transmission to deployed submarines. Unfortunately, the comms and data arriving at SSIXS receivers produced a paper tape, which had to be torn off and fed manually into Verdin transmitters to relay to the submarines.

To improve operational efficiency, NELC engineers developed the Integrated Submarine Automated Broadcast Processing System to automate the interface between SSIXS and Verdin. With that new capability in place, Navy uniformed

---

[41] "Two NOSC employees, former CO pass away," NOSC *Outlook*, October 20, 1978, 3.
[42] "SSC Pacific celebrates 70 years on the Point," SSC Pacific *News Bulletin*, June 2010, 15.
[43] See NOSC *Outlook* April 22, 1977 and May 5, 1978.
[44] "NELC's highest honors," NELC *Calendar*, April 14, 1972, 3.

personnel in Cutler, Maine, switched on the system on December 20, 1976, and began transmitting vital operational information to submerged submarines.[45]

Admiral I.C. Kidd, Jr., who after his tour as Chief of Naval Material had returned to major at-sea command as Commander-in-Chief, U.S. Atlantic Fleet, was enthusiastic about the benefits of the new technology:

> Commencement of the world's first operational VERDIN [sic] multichannel submarine broadcast will go down as an historic event in the annals of naval communications. This giant step forward in the command and control of our submarine force is the culmination of years of hard work and dogged determination by everyone associated with the program.[46]

Incidentally, regarding the use of SSIXS for the downloading of message traffic and tactical data to Verdin, the information exchange system itself recorded a major milestone in the spring of 1976, as it transmitted its first message between Commander, Naval Submarine Force Atlantic, and USS *Batfish* (SSN-681):

> SSIXS is composed of satellites, submarines and shore-based communications terminals… Using SSIXS, a submarine commander can elect to receive only messages of concern to him, or those which are rebroadcast regularly. Also, SSIXS can dramatically reduce the time away from mission functions by shortening pre- and post-communication operations.[47]

NELC command histories in the early 1970s highlighted additional achievements in submarine communications: for example, the Integrated Submarine Communication System provided Trident submarines (scheduled to go to sea later in the decade) an external communication system that would operate under such severe conditions as a world-wide conflict, resulting in a survivable command control link to the Trident platform with minimum personnel effort.[48]

Additionally, NELC contributed significantly to the Survivable Satellite Communications System with its efforts on the experimental model submarine communications terminal for the joint service program. Operating at extremely high frequency (EHF), the terminal was designed for use on a mobile platform.[49] It was evaluated at the periscope simulator test facility described below.

Critical to the success of these communication technologies were studies of

---

[45] "NOSC plays major role in developing world's first multiple submarine broadcast system," NOSC *Outlook*, April 22, 1977, 1.
[46] Admiral I.C. Kidd, Jr., quoted in NOSC *Outlook*, April 22, 1977, 1.
[47] NELC *Calendar*, April 23, 1976, 1.
[48] NELC Annual Report FY1973, Volume II, 27.
[49] NELC FY1974 Annual Report, 31.

ionospheric propagation, conducted at NELC's most remote sites: Sentinel, Arizona; Fairbanks, Alaska; Greenland; and on the high plateau between the volcanoes on Hawaii's Big Island. The communication stations at those locations were "'sounding,' that is, transmitting VLF signals into the ionosphere at different locations to determine atmospheric interference with VLF transmissions."[50]

With establishment of the Naval Ocean Systems Center (see Chapter 15), Dick Eastman transferred from his leadership of the program office to head the Communications Systems and Technology Department, a position he held until his death in October 1978. In recognition of his substantial contributions to submarine communications capabilities, he was presented the Navy's second highest award, the Superior Civilian Service Award, in mid-April 1977.

Despite the loss of its leader, the superb staff and practices developed by Eastman continued their significant contribution to submarine communication capabilities, playing an essential role in development of integrated radio rooms for USS *Los Angeles* (SSN-688) class and Trident FBM submarines, to be discussed in Volume II. The Enhanced Verdin system "provides vastly improved strategic command and control communications from the Joint Chiefs of Staff and the National Command Authority to submarines and aircraft."[51]

Satellite systems

As previously described, NELC had taken the leadership role in developing new fleet communication capabilities employing satellites, designated by the Naval Material Command as the systems engineering agency for development of the Fleet Satellite Communications System, a joint Navy-Air Force project:

> The system is expected to materially improve military worldwide operations by using four satellites placed in synchronous, equatorial orbits by NASA. It will include a number of Navy information exchange systems, and should be fully operational by the 1980s.[52]

NELC's tasking was system level engineering and integration planning.

---

[50] NOSC, *Fifty Years of Research and Development on Point Loma*, 68.
[51] *Fifty Years of R&D*, 116.
[52] NELC TD 275, NELC Annual Report FY1973, Volume 1: "Management and Technical Highlights," 25.

A handful of IXSes—Information Exchange Systems—were developed for inclusion:

--SSIXS (Submarine Satellite Information Exchange System): A circuit to be employed by submarines for two-way communication with shore sites. It was installed at Commander, Submarine Force Pacific in Hawaii in late 1972 for technical evaluation. (See also “Submarine communications” above)

--CUDIXS (Common User Digital IXS): Representing a follow-on to the NELC ship-shore-ship data link, it was designed to provide full-period terminations to the ships on which it would be installed.

--SSTIXS (Small Ship Teletype Information Exchange System): Developed for ships on which ship-shore-ship full-period terminations were not installed. It allowed these units ship-to-shore access.

--TADIXS (Tactical Data IXS): Provided NTDS-equipped surface ships the technology for using the system input/output devices and processing equipment to broadcast NTDS-formatted information ship-to-shore via any of the satellites. NTDS information and properly formatted data could also be exchanged between surface ships.

--TSCIXS (Tactical Support Center IXS): Designed for ASW forces ashore, at sea, and in the air, it provided a netted secure high-speed digital data exchange capability to TSC shore centers and selected ships and aircraft.[53]

Getting down to earth on satellite communications (SATCOM), NELC personnel designed and built a testing tower at a small facility near the Coast Guard lighthouse at the southwest tip of Point Loma. The tower simulated a submarine periscope, on which was mounted the submarine terminal for the Survivable Satellite Communications program. The forty-foot-high tower was “mounted on a large axle and driven hydraulically to rotate about that axle,” and was thus programmed to provide roll, pitch, and yaw motion.[54] Additionally, a hydraulic shaker on the tower was used to couple vibrational modes onto the mast of the system being tested.[55] The combination of roll and vibration simulated the motion a ship would experience at sea. Although it was designed specifically for the Type 16 periscope planned for that program, it could be modified to simulate sea motion

[53] NELC Annual Report FY1973, Vol. I, 13.
[54] “New simulator aids SATCOM tests,” NELC *Calendar*, September 28, 1973, 4.
[55] “NELC Today,” January 1975.

for any mass weighing up to four hundred pounds. The tower later was used extensively for testing of EHF SATCOM submarine terminals.

While one group of NELC employees worked to develop satellite communication capabilities, another group worked to prevent their disruption. It had been theorized, and later authenticated, solar flares—mammoth eruptions of super-heated gases from the sun's surface—could have disastrous effects on earth-based communications. Scientists at the NELC Astro-Geophysical Laboratory, based at La Posta in the Laguna Mountains about an hour's drive east of San Diego, studied and monitored solar activity using their sixty-foot-diameter radio telescope. During the numerous Apollo space flights of the early 1970s, they were responsible for close attention to events on the sun with the potential for disrupting communications between NASA officials on the ground and astronauts circling the globe or headed for the moon.[56]

Contributions to QUALCOMM start-up

Earlier chapters cited essential contributions of contractors to Navy technical programs, entailing a well-established, often very large business competing for and winning a contract to develop and produce operational torpedoes, for one example already mentioned, or generate components of a command and control system.

An interesting example of contractor support and resulting success occurred when NELC sought private industry assistance in developing a satellite communications capability for a Defense Advanced Research Projects Agency program. This is the contractor's statement on the outcome, from Irwin Jacobs:

> Two of the founders of Linkabit, Irwin Jacobs and Andrew Viterbi, created advanced communications technologies in the early 1970s for the Navy under a … contract [that] involved activities in satellite communications, including early work on frequency-hopped Code Division Multiple Access (CDMA) to enable the Navy to maximize satellite communications efficiency. Linkabit became a highly successful company, later seeding many telecommunications companies in the San Diego region. Jacobs and Viterbi left in 1985 and shortly thereafter founded Qualcomm along with five others from Linkabit. CDMA has become the foundation of today's third generation cell phone technology, supporting voice and broadband mobile data worldwide.[57]

---

[56] NELC *Calendar* January 29, 1971 (Apollo 14) and December 8, 1972 (Apollo 17).
[57] Space and Naval Warfare Systems Center Pacific Public Affairs Officer email to SSC

Success requires major move

A major article in the May 22, 1970, highlighted the downside of project success, as personnel of the Integrated Flagship Data System (IFDS) project were forced to move out of Battery Humphreys. (One of Point Loma's major World War II coastal defense batteries, the facility was completed in October 1943, named for Captain Charles Humphreys, the first commanding officer of Fort Rosecrans. It was acquired by NEL in 1959.) NEL had been using the refurbished facility since the early 1960s for development and assembly of command control system technology, beginning with the Command Ship Data System (CSDS). A specialized system for the National Emergency Command Post Afloat, it was installed on the converted command ship USS *Wright* (CC-2). The Fleet Flag Data System was initiated as an offshoot of CSDS to acquire, process, store, and display large quantities of operational data, giving fleet commanders afloat the same capabilities as commanders-in-chief in Europe.

IFDS extended those data-handling capabilities to fleet flagships, specifically for First and Seventh Fleet. NELC was responsible "for system design, assembly, test, evaluation, crew training, documentation, and technical assistance in shipboard installation and evaluations."[58] Initial shipboard installation in June 1970 on USS *Providence* (CLG-6), the First Fleet flagship, provided the interface with the Ship-Shore-Ship Data Link for receipt and transmission of digital data from satellites.[59] (*Providence* also was employed in 1969 for the first demonstrations by NELC of fleet satellite communications.)

Removal of IFDS equipment from Battery Humphreys and installation on *Providence* left project personnel with insufficient hardware to complete software development. That necessitated the move in the summer of 1970 of ninety lab and contractor personnel, plus twenty-five ship crewmembers on-site for training, to other locations like the Applied Systems Development and Evaluation Center in Building 33, with office space provided in trailers near the building. With a hard deadline looming, the team needed to run computer programs "24 hours a day, seven days per week, through December, and we're simply not going to have that requirement satisfied," said project manager G.N. "Neil" Hampton. In order to

---

Pacific Commanding Officer and Executive Director, May 27, 2015.

[58] NELC Annual Report for Fiscal Year 1970, NELC Technical Document 100.

[59] NELC Annual Report for Fiscal Year 1971, NELC Technical Document 150, 15.

fulfill their requirements on time, his team cooperated with other Center groups through computer time-sharing.

With the move of IFDS, "the mice and rattlesnakes stand ready to take command of Battery Humphreys," according to the *Calendar* article, suggesting challenges that had faced personnel working there.

Radar development expanded

The Point Loma laboratory had been involved in radar technology projects since its very early days. Chapter 3 discussed studies initiated in the fall of 1942, one of which related some very foundational work: "The investigation described herein was undertaken to determine certain of the basic laws governing so-called Radar echoes from metallic surfaces over the ocean."[60]

More than twenty reports on the technology had been published by the end of World War II.

In the mid-1970s, studies were undertaken to improve radar imaging of ships, resulting in development of two-dimensional imaging capability of significant interest and relevance for target identification, weapons targeting, and damage assessment.[61] The approach, capable of capturing images of both ships and aircraft from a fixed site on Point Loma, was termed Inverse Synthetic Aperture Radar. As explained by one of the principals in a book he wrote after his retirement:

> *Inverse synthetic aperture radar* (ISAR) [emphasis in original] is a version of SAR [Synthetic Aperture Radar] that can be used operationally to image targets such as ships, aircraft, and space objects. The technique also has application to instrumentation radar for evaluating radar cross section of targets and target models…A SAR map is generated from reflectivity data collected as the radar platform moves past the target area to be mapped, whereas ISAR target imagery is generated from reflectivity data collected as the target rotates while remaining in the radar beam… The aspect (viewing angle) rotation of the target relative to the radar is used to generate the target map, which is the *target image* [Emphasis in original].[62]

---

[60] Lloyd Anderson, John B. Smith, F.R. Abbott, Lt. Roger Revelle, USNR, "Radar Wave Propagation," 30 November 1942 (NRSL Report WP-2), 3.
[61] *Fifty Years of Research and Development*, 99.
[62] Donald R. Wehner, *High-Resolution Sonar,* Second Edition, Boston/London: Artech House, Inc., 1995, 341. Wehner worked at the Point Loma lab his entire twenty-six-year federal career. He headed the Radar Branch from 1973 until his retirement in 1991, leading

Dr. Juergen Richter of the Propagation Technology Division spearheaded other efforts to improve radar technologies, including "invisibility." Often, an aircraft would be plainly visible to the eye, but invisible to radar. Richter developed a radar sounder to study electromagnetic radiation in the troposphere. Like the bathymetric data gathered by earlier scientists to study how water affected sonar propagation, the radar sounder recorded the behavior of radar radiation through various conditions of temperature, humidity, etc. In particular it calculated a signal's refractive index, the ratio of velocity of propagation for radio waves in a space-like vacuum to the observed velocity in the troposphere. Using the radar sounder, Richter measured the structure of the troposphere in fine scale, discovering mirage effects that bent microwave radiation to produce peculiar readings (similar to the way a desert floor appears to shimmer like water in the distance). In addition to aiding the Navy, his research contributed to civilian agencies' ability to predict and measure temperature inversions creating the infamous smog that plagued Southern California from the 1940s to the 1970s.[63]

Richter's radar sounder was incredibly sensitive: he stated it could detect an object the size of a common housefly at an altitude of 10,000 feet. In the course of his work, he incidentally found common airborne insects "ride" waves and ripples and wind shears through the atmosphere and could produce false or confusing readings. His measurements contributed to understanding phenomena like locust swarming. Richter recalled, "That led to a lot of interest by the Department of Agriculture. We noticed that especially at night the majority of insects fly above the stratus layer because they navigate by the stars or like better visibility above the clouds."

This provided support and assistance to Department of Agriculture experiments, for example, releasing sterile male insects into the atmosphere at the right time and place to mate, interrupting the cycle that produced large populations of pests.[64]

Dr. Richter's work was applied to a number of other military and civilian uses. For example, his measuring of wave motion in the troposphere contributed to understanding that bane of air travelers, clear air turbulence. Establishing the

---

development of substantial improvements in Navy radar capabilities.

[63] "Radar sounder explores secrets of atmosphere, discovers breaking waves," *Calendar*, February 27, 1970, 2.

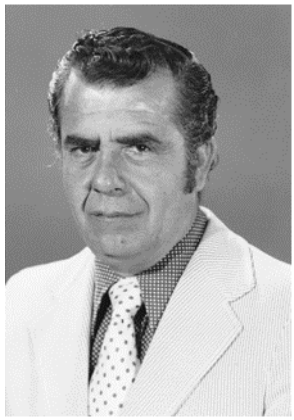
[64] Dr. Juergen Richter oral history interview conducted by Tom LaPuzza September 11, 2012, 24-25.

Tropospheric Propagation Branch, consisting of himself, one technician, and a Navy petty officer billeted for meteorology, he built successive generations of sounders, each more sophisticated. For his accomplishments Richter received the NELC Honorary Award for Achievement in 1970.[65]

Also, as reported of George Wilkins in Chapter 11, Richter was one of the four technical personnel selected to receive the Navy Meritorious Civilian Service Award during the first year of operation of the Naval Ocean Systems Center in 1977. (Before the decision was made the following year to replace the NELC and NUC organization-wide citations with the Lauritsen-Bennett Award, the Navy Meritorious was determined to provide an appropriate level of recognition to outstanding employees. Additionally, as noted in Chapter 10, Dr. Erhard Schimitschek was selected for the first NOSC DP-V under the Personnel Demonstration Project. Richter was also one of only three so selected.)[66]

Dr. Erhard Schimitschek

Dr. Juergen Richter



Richard "Dick" Eastman

Drs. Schimitschek and Richter, both of whom immigrated to the U.S. from Europe, were two of only three of the Center's brilliant scientists selected as DP-Vs under the Personnel Demonstration Project at the Naval Ocean Systems Center. Dick Eastman established the very first program office at NEL, and received the Navy Superior Civilian Service Award.

[65] *Calendar*, March 13, 1970, 1. (The branch grew over time to a slightly larger staff.)
[66] NOSC, *Outlook*, January 18, 1991, 1. The third was Dr. Keith Bromley.

Accuracy check sites

Sonars, radars, navigation systems, electronic support sensors—such are the "eyes and ears" of a Navy ship. Its operational capabilities, and as well the lives of its crew, depend on the precision operation of its sensors. In the early 1960s, NEL was selected lead lab to develop a capability to determine the accuracy of those sensors. The result was the Fleet Operational Readiness Accuracy Check Site (FORACS). The first FORACS range was installed at San Clemente Island. Three precision-surveyed optical tracking stations on shore, with various sonar, radar, and optical targets, allowed precise calibration of sonar, surface search radar, fire control radar, gyrocompass, periscopes, navigational instruments, and even helicopter-mounted anti-submarine warfare sonars. Communication and computer equipment to gather sensor performance data was installed in a central control building, providing a twenty-four-hour turnaround time for preliminary sensor operational data.

The SCI range was completed in 1965, followed by one at Nanakuli in Hawaii, and two on the East Coast at Guantanamo Bay, Cuba, and Cape Cod, Massachusetts. The Center also assisted the North Atlantic Treaty Organization (NATO) in establishing sites in Norway and on the island of Crete.

FORACS sensor evaluation involved two distinct phases. The first, at dockside, lasted about six hours, during which the commanding officer and crew were briefed, shipboard equipment was checked, and a communications link was established and verified. In the second phase, the ship steamed as instructed through the test range while "test engineers monitor data gathering, provide sensor target signals and determine the ship's reference heading, independent of ship's own equipment. This second test period required about nine hours at the test range."[67]

FORACS sensors provided data that gauged the functioning of both the ship and its personnel. Glenn Nye, who at the time headed the Center's Fleet Support Program Office, said,

> To the ship, it gives a measure of sensor and operator performance which in tum tells the effectiveness of the maintenance performed by ship personnel. FORACS provides a measure of a vessel's combat readiness, which operational commands must know.

[67] *Calendar*, February 13 1970, 3.

In 1969, NELC set up a Sensor Accuracy Check Site (SACS) at the Long Beach Naval Shipyard to augment services provided by FORACS. The major difference between the two sites was the ship maneuvered into SACS and was moored there in a stationed position, rather than steaming in various directions within the range. Test signals were transmitted by thirty-one transducers positioned in a nearly complete circle (300 degrees) around the ship.[68] It measured performance of sonar systems, including determining bearing accuracy and range accuracy (distance). The following year's command history added,

> Checks can also be made on the performance of related signal processing and display subsystems. Shipyards will use SACS to certify installation of sonar systems, provide performance data during preoverhaul inspections, and to diagnose system problems.[69]

It noted a sonar system could be evaluated at SACS in a day.

The FORACS and SACS functions were transferred to other Navy commands in the fall of 1976.[70] NELC retained responsibility for development of equipment and guidance of technical progress.

Helen Blanchard

One of the FORACS team members developed a data bank containing vital information on every ship and ship's system tested over a three-year period in the late 1960s to early 1970s. Consolidation in this manner was significant in that "reports, based on this information, enable the Chief of Naval Operations, system designers and type commanders to determine overall fleet readiness of ships' sensors."[71]

The formulation of that data bank was completed by Helen Blanchard, a physical science technician assigned to the group. In mid-1971, Blanchard was selected to head the site's Data Analysis Section, and was thus responsible for all

[68] Naval Electronics Laboratory Center Annual Report for Fiscal Year 1970, NELC Technical Document 100.
[69] Naval Electronics Laboratory Center Command History for Calendar Year 1970, 8.
[70] NELC *Calendar*, September 24, 1976, 1.
[71] NELC *Calendar*, September 24, 1971, 1.

Helen Blanchard

FORACS computer programming management. Based substantially on those efforts, she would be named as NELC Woman of the Year for 1971.

Blanchard would advance from that position to accomplish an impressive number of firsts, including first woman to head a Center technical division, first to spend a night at the facility on San Clemente Island, first woman aboard a British warship on the high seas, incidentally while Prince Charles was aboard. (Her supervisor had sent her to HMS *Minerva* to view the operation of its sonar system; she'd been trained in the operation of sonars and it was judged a valuable opportunity for her to observe shipboard sonar operation.)

Blanchard would also be the first of her gender selected for the Naval Ocean Systems Center's premier honor, the Lauritsen-Bennett Award.[72]

On her way to that prestigious award, she had joined the Point Loma laboratory's Toastmasters Club, which, in fact, she was not qualified to do. When Blanchard showed up for her first lunch-time meeting, it was noted Toastmasters membership was not open to women. The Navy Electronics Laboratory men who were members, hoping the experience and training would improve their public

[72] NOSC *Outlook*, July 5, 1991, 1.

speaking and presentation skills, considered it reasonable for Blanchard to do the same. They enrolled her in their chapter by her initials, choosing not to mention her gender to Toastmasters officials. And that simple courtesy of her male associates would lead to "the biggest honor of my life," as, in 1986, she was elected international president of Toastmasters, the first woman to hold that position.

A staunch advocate of the organization that would have denied her entrance but for her male NEL/NELC associates, she once said:

> Toastmasters is probably one of the most beneficial programs that people can attend. I've seen it change people's lives… To know that you're communicating well is something that is so important for every person who's in this world. I don't care if you work or not. I mean, in the working situation it's critical, but even without that… It did me a world of good—I can't tell you how much—and it still does.[73]

As essentially the first woman "officially" admitted to the organization, she obviously scored a number of firsts there, including the first woman to earn the coveted Distinguished Toastmaster designation. Based on her elevation to the club presidency, she visited Washington, D.C., in the spring of 1986, and the May 15 event was celebrated by the district's mayor as Helen M. Blanchard Day.[74]

Even without those many firsts, Blanchard's life, chronicled in a book she cowrote, was beyond impressive.[75] Born in the small northeastern Nebraska town of Pender, which was determined by the Supreme Court in 2016 to be entirely within the Omaha Indian Reservation, Blanchard graduated from high school at fifteen. Based on specific studies she undertook as a junior and senior, she earned her teaching credential and "I was sixteen the entire year that I taught in this one-room schoolhouse in Wisner, Nebraska. There were twenty-four children, in all eight grades."[76]

Other technologies

In addition to major programs, NELC managed a number of smaller efforts

[73] Helen Blanchard interview conducted by Tom LaPuzza, September 24, 2012, 36.
[74] Naval Ocean Systems Center *Outlook*, May 30, 1986, 2.
[75] Helen Blanchard with Deanne Durrett, *Breaking the Ice*. (San Diego, California: HBlanchard Enterprises, 2008).
[76] Blanchard interview, 1.

in technology areas related to (and some not) its assigned major areas of responsibility:

Weapons: NELC's expertise in electronics made it the Navy's choice for developing specialized components of weapons systems. It developed the BRAZO (Spanish for "arm") anti-radiation missile, which flew its first test flight at Holloman Air Force Base, New Mexico, on April 16, 1974. BRAZO used a broadband frequency receiver to home in on signals from the fire control radar of an enemy warplane. This enabled it to attack enemy jets head-on without the need to detect infrared radiation. Mounted on a Sparrow air-to-air missile and launched from an Air Force F-4D Phantom jet, the system performed perfectly at its second firing in September, when a BRAZO-equipped Sparrow successfully intercepted a target drone over the White Sands Missile Range in New Mexico. In November, the system went three-for-three as it intercepted another drone at White Sands. BRAZO was part of the Electromagnetic Radiating Source Elimination (ERASE) program; despite successful testing, both the missile and the program were cancelled in those budget-restricted times.[77]

Before its cancellation, however, BRAZO was responsible for one of the most curious sights on the Point Loma landscape. Off Catalina Boulevard near the Transducer Evaluation Center, a BRAZO-modified F-4 Phantom, minus its engine, was mounted on a frame a few feet off the ground. The site, thought to be the highest on Point Loma, provided the electromagnetic and environmental conditions necessary for system ground tests. Again, simulation was key to development: NELC was able to simulate the functions necessary for in-flight acquisition, tracking, and launch of a BRAZO weapon against military aircraft operating in the offshore maneuvering ranges west of Point Loma, all from a rig that remarkably resembled a display at an aircraft museum.[78]

Communications: NELC created two communication technologies in the mid-1970s that demonstrated both technical mastery and a wry talent for appropriate acronyms: ALOFT (Airborne Light Optical Fiber Technology) proved fiber optic cable was a feasible medium to replace conventional wiring for systems applications in aircraft. NELC had been working in fiber optics since 1970.[79] The ALOFT test on May 6, 1976, employed an A-7 Corsair jet carrying a

---

[77] *Calendar*, April 26, 1974. Also, NELC *Station Journal* April 15, September 27, and November (no date given) 1974.

[78] *Calendar*, August 13, 1976.

[79] "Fiber optics researched for Navy communications systems," NELC *Calendar*, March

Navy tactical computer modified by IBM so that external signals to peripheral avionics took place over fiber weighing twenty-one times less than the necessary 300 copper wires. The Corsair conducted a successful bombing and rocket firing demonstration at the Naval Weapons Center.[80] Light and durable, fiber optic cable is less subject to electromagnetic interference than copper wire and its weight reduces fuel consumption. NELC's pioneering work, the first such successful test, began a decades-long, progressive effort to replace wire in aircraft.

OCCULT (Optical Covert Communications Using Laser Transceivers) must take its place in the acronym hall of fame. "The OCCULT system has made feasible a whole new spectrum of covert naval tactical communications," (e.g., secret messages), enthused the *Calendar*. Naming aside, OCCULT extended NELC's work with lasers as a communication medium by overcoming the challenge of keeping two laser transceivers, mounted on ships at sea, connected as the ships pitched and rolled over the waves. The system enabled reciprocal tracking in the two transceivers, each sensing the incident direction of the received beam and answering with a transmitted beam of CO_2 laser light in the same direction. The system was capable of transmitting one video channel, four 15-kHz analog channels, and one twenty-kilobit/second digital channel simultaneously.[81]

Hydrofoils: During the 1960s and 1970s, Navy ship designers experimented with a number of radical designs to increase speed and fuel efficiency. For example, Tom Lang's work with the Semi-Submerged Ship was discussed in the previous chapter. NELC was not in the ship design business (and, in fact, neither was the weapons laboratory), but played a substantial role in planning potential missions for the several classes of hydrofoils the Navy commissioned at the time. In 1971, *Calendar* articles detailed plans to conduct a month-long study of USS *High Point* (PCH-1) to develop mission applications and electronics subsystem requirements, and to investigate the feasibility of employing USS *Flagstaff* (PGH-1) as a platform for a six-inch gun. NELC was also responsible for the test and evaluation master plan (TECHEVAL and OPEVAL) for USS *Pegasus* (PHM-1) when it was launched in late 1974, and for acting as combat system integration monitor for the German PHM variant.[82]

Biomedical engineering: In a move calculated to improve the lot of ailing

16, 1973.

[80] *Calendar,* March 21, 1976.

[81] *Calendar,* February 11, 1977.

[82] NELC *Calendar,* November 8, 1974 and January 28, 1977, respectively.

members of the local Navy community, NELC teamed with the San Diego Naval Hospital to bring technology to bear on challenges associated with patient care: "Hospital officials expect faster service and better delivery of medical care for more persons under a biomedical engineering program just initiated jointly by the two San Diego commands."[83]

The facility, according to coverage of a press conference held at NELC to announce the cooperative effort, was the largest military hospital in the world, with a daily patient load of more than 1,500. Impressive statistics included 197,000 laboratory tests; 89,000 prescriptions; and 40,000 x-rays monthly. The initial NELC contribution was in processing electrocardiograms using its new IBM 360/65 computer. Typically, the hospital processed 3,000 ECGs per month, with the actual process requiring thirty minutes and normal turn-around time of ten days. The Center's computer reduced processing to fifteen seconds and turnaround time to overnight. As a result, the hospital, which previously served twenty-five percent of the eligible cardiac patients in the San Diego area, became the regional cardiac center and doubled its ECG capacity to six thousand per month.[84] Over the next several years, the small biomedical engineering team would deliver a number of significant improvements to the Navy medical community, including the Remote Medical Diagnosis System, which provided small ships without a physician the ability to confer with Navy doctors at ashore medical facilities via teleconferencing. Also, a system was designed to allow continuous monitoring of the cardiac ward's eight most at-risk patients. And a stand-aid wheelchair for improving the lives of those confined to wheelchairs was developed.

Vision research: In July 1968, experimental psychologists Dr. Carroll T. White and Dr. M. Russell Harter announced they had developed a new way to diagnose nearsightedness, farsightedness, and astigmatism in human vision by recording brain waves in persons watching a flashing checkerboard pattern. By measuring different electrical activity in the brain as the pattern changed, and comparing recordings, their computer detected which image was clearer to the participant.

Harter termed the discovery "pure and simple serendipity." Their focus at the time was conducting pattern recognition studies related to Navy sensor information displays. Seeking to improve radar and sonar system displays, their

[83] NELC *Calendar*, November 19, 1971, 1.
[84] NELC *Calendar*, March 31, 1972, 3.

research concentrated on changes in the brain's electrical energy level when a test subject reacted to a stimulus, specifically the image of a black and white checkerboard flashed at short intervals. Noting a substantial difference in that energy level when an image was blurred or focused, "implications of the findings dropped in their laps."[85] Obviating the necessity of a test subject response to a visual stimulus meant young children, even babies, could be tested for vision impairment. In 1975, Drs. White and Harter shared a Navy patent award of $11,235 for their joint development of the method.[86]

Dr. Carroll White (left) and Dr. Russell Harter, developing Navy information displays, chanced upon a method for diagnosing vision deficiencies.

Dr. White's decades of basic research involved "critical theory and data regarding eye movements, muscle fatigue, display lighting, radar time compression displays and many other vital aspects of human performance in connection with military systems."[87]

"Packaging": In a discussion about the Naval Tactical Data System in Chapter 6, one of the NTDS principals was reported as specifying transistors for the system. Editorial comment followed up with the statement that large numbers of fragile vacuum tubes was a non-start for shipboard applications. Electronic technology was definitely an improvement over glass-enclosed tubes, but even those are not proof against the shock and vibration occasioned by a ship plunging through heavy seas. To provide some added measure of protection against such potential damaging threats, NELC maintained a small group of engineers and

[85] NELC *Calendar*, July 5, 1968, 2.
[86] NELC *Calendar*, December 5, 1975.
[87] *Calendar*, December 19, 1969, 5.

technicians who specialized in countering the effects of shipboard "vibration, shock, heat, humidity, RFI (radio frequency interference)…"[88]

The Equipments Effectiveness Division, based on at-sea measurement of shipboard stressors, developed an integrated packaging program of standard cabinets/enclosures, cooling capability, wiring, and connectors suitable for data processing, communication, radar, sonar, and weapon systems. Those included special housings for the electronics hardware. Innovations included "flat ribbon cable," which provided "superior heat dissipation, greater current capacity and advantages in weight saving."

Digital control systems: Related earlier in the chapter were the efforts of Dr. Robert Kolb and Lieutenant Commander Floyd Hollister in providing a digital control system for the sixteen-inch gun batteries of USS *New Jersey*. The pair were assigned to a division specializing even in the 1960s in digital control technology. NEL/NELC apparently was substantially ahead of the game, as in early 1976 Assistant Secretary of the Navy (Research and Development) H. Tyler Marcy outlined in testimony to Congress the Navy's R&D objectives. The second of those was the increasing employment of digital technology in command and control systems.[89] The ASN cited, moving into the next decade, an "increasing need for system integration, not just within a platform, but encompassing entire task force operations, including the command and control structure, at sea and ashore."

That would provide substantial future work for the Point Loma laboratory.

Appropriate project spaces lacking

The technical achievements described above indicated an organization with substantial responsibilities to the Navy, and particularly to the fleet, which it was meeting fairly successfully. At the same time, the nemesis that had plagued the NOTS/NUWC Pasadena location—inadequate facilities—now reared its ugly head on Point Loma. From the initial single building with about half a dozen personnel, NELC had grown substantially, particularly early on when its

[88] "Packaging Program Proves Its Value," NELC *Calendar*, January 17, 1969, 3.
[89] Testimony of H. Tyler Marcy to House Armed Services R&D Subcommittee on February 23, 1976, reported in NELC *Calendar*, March 26, 1976, 1 & 3.

headquarters and laboratory structure, Building 33, was constructed in the early 1950s. Other buildings were constructed around Building 33, and structures on the waterfront that were once part of the Quarantine Station had been acquired for the lab's sea-going components. The station had operated there for more than fifty years; the property was turned over to the Navy in the middle of World War II.[90]

Of course, there was some "reverse" progress in the facilities area: less than a year after the Chief of Naval Material directed the relocation of Naval Undersea Warfare Center (NUWC) headquarters from Pasadena to San Diego in July 1968, NELC had to transfer, in addition to its oceanographers, thirty-five acres of its waterfront property to NUWC, plus acreage on top of Point Loma on which the Submarine Research Facility and the Transducer Evaluation Center were sited. Both unique facilities were now under the control of NUWC.

As it was ordered to give up large sections of property previously under its control, and as it moved from development of system components to the systems themselves, NELC found itself with a scarcity of facilities, particularly a specific type. The Center's annual history reported: "About 41 percent of space currently available at the Center for RDT&E functions is substandard because of structural unsuitability, extensive deterioration, hazards to personnel and equipment, and operational deficiencies."[91]

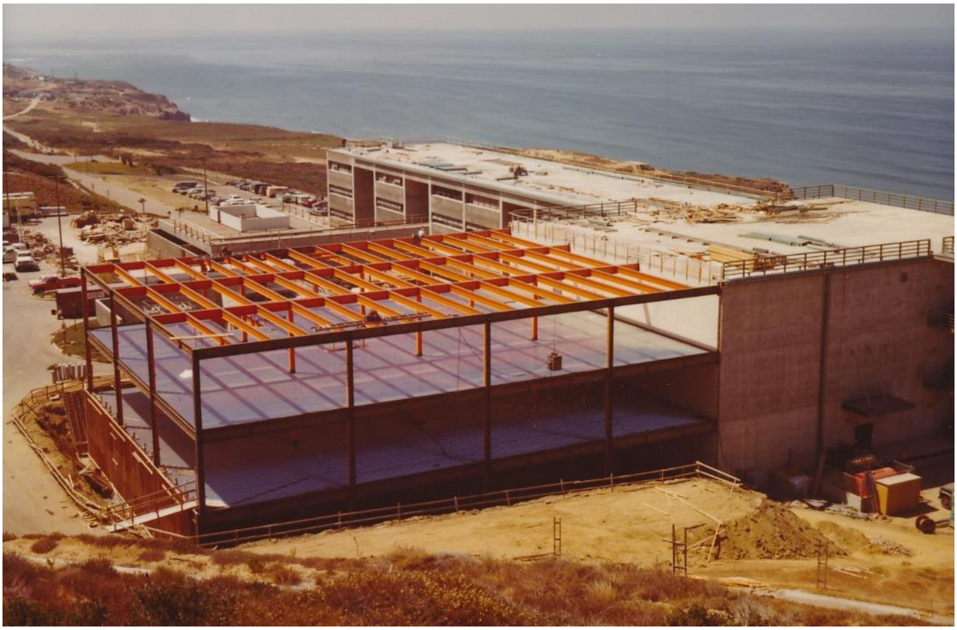
Of particular concern was centrally located electromagnetically secure space; the limited amount of it was "widely scattered," with the result "Lack of adequate secure space for classified development continually hampers NELC activities."

As a result, one of the most significant events of the 1970s for NELC might well have been construction of the Electronic Development And Test Laboratory (EDATL). It would provide, for the first time, an appropriate facility for NELC's mission-required large-scale, full-system integration and testing of surveillance,

---

[90] "The Quarantine Station at La Playa was established in 1888, and work upon the buildings was begun in 1891. The Marine Hospital in connection with it occupies nearly the site of the old hide houses. These buildings are to be turned over to the navy department and the site used as a coaling station, the quarantine station and hospital being removed elsewhere." William Ellsworth Smythe, *History of San Diego: 1542-1907: An Account of the Rise and Progress of the Pioneer Settlement on the Pacific Coast of the United States* (San Diego: The History Company, 1908), 702. The Quarantine Station continued operating in a number of buildings—101, 121, 190—until the property was transferred to the Navy in 1944 and to NEL in 1949. See Chapter 14 for a discussion on the hide houses and Appendix D for a more complete history of the Quarantine Station.
[91] "MILCON Program," NELC Annual Report FY1973, Vol. 1, 8.

command and control, and communications technologies. Planned as three increments (in Navy Military Construction parlance: P-052, P-053, and P-057),



Critically important to the purpose of the Electronic Development And Test Laboratory (and to NELC command and control technology development) was the lead-shielded laboratory space, shown under construction.

the structure, informally Building 600, would provide more than 125,000 square feet of working space, including an office wing of four floors and 75,000 square feet of electromagnetically secure laboratory space. P-052 was included in the Military Construction Bill submitted to Congress for FY74, which did not guarantee success, but certainly helped. The wartime expansion with hundreds of structures sprouting on the desert floor at China Lake within a few years (see Chapter 4) was a thing of the past, the far distant past, and defense dollars in the early 1970s, especially for facility construction, had been drastically reduced.

Fortunately, P-052 remained active in the bill, passed by Congress and signed by President Nixon as 1973 ended. The January 18, 1974 *Calendar* featured an artist's concept of the total project, with text explaining which part of the structure was to be constructed first with the $3.5 million MILCON funding. On August 12, the Navy's resident officer in charge of construction and an official of the winning contracting firm joined Center Commander Captain N.D. Harding and his TD Dr. Clarence Bergman in an unusual groundbreaking ceremony. Rather than the typical ceremonial shovels to turn over some dirt, the group planted a Monterey pine tree, reflective of the effort begun a few months earlier to conserve the natural Point Loma environment. Actual construction was set to begin immediately.

In addition to the obvious benefit of providing space for full-scale integration and testing, one of the important intentions behind the structure was to "eliminate the very marginal facilities provided by rented and leased office-type trailers, and vacate the highly flammable World War II Army barracks now being utilized."[92]

As the increasing potential for merging the two Navy laboratories on Point Loma progressed, NELC was tasked with initiating a new entity, the Integrated Combat System Test Facility. Scheduled for location in the EDATL facility, "the major role of the new test center will be to test improvements and modifications to existing combat systems and provide support for the upgrading of combat systems during their operational life cycle."[93]

Facility upgrade

"If you like to think small, imagine wearing your telephone on your wrist," suggested Pat Polakowski in a "fantasy" attention-catching lead for which she was noted.[94] (Polakowski was *Calendar* editor for several years and the assistant public affairs officer of NELC and the Naval Ocean Systems Center.) She went on to relate that "NELC teamed with microelectronics," providing definitions and descriptions of the integrated circuit fabrication work at the lab. Several months before the release, the Center, seeking expertise from private industry, had hired Dr. Olof Lindberg to head its Microelectronics Division. Lindberg was quoted substantially in the special issue of *Calendar* commemorating the NELC Silver Anniversary, which featured a two-page center spread of that technology

[92] NELC Annual Report FY1973, Vol. 1, 8. Interestingly, forty-five years later, the Point Loma Navy lab still occupied fifteen of the forty major structures in the Barracks Area, according to the Center's facilities office. Dr. Laura Baker emails to Tom LaPuzza, February 7 & 8, 2019.
[93] NELC *Calendar*, Jan. 28, 1977, 1.
[94] Pat Polakowski, NELC news release about microelectronics, November 24, 1970, 1.

development.[95] In one of its critical points, the article stated, "For the Navy, microelectronics means reliability, low maintenance, simplicity and small size… It means weight reduction, less cooling requirements and lower logistics costs."

The article detailed NELC's determined push into the technology, symbolized by its transformation of an abandoned World War II coastal defense structure, Battery Ashburn North, into its Integrated Circuit Fabrication Facility (ICFF), popularly known as the Microelectronics Laboratory.

Several years after the anniversary celebration, in one of his first official acts as NELC Commander, Captain N.D. Harding joined his technical director Dr. Clarence Bergman and division head Lindberg at Battery Ashburn to add an important new aspect of microelectronics to the Center's venue. Shovels in hand, they literally broke new ground with the start of construction of the Large-Scale Integration (LSI) Prototype Facility in January 1972.[96] The structure gave the Microelectronics Division a spacious new laboratory to double the size of its clean rooms (ultra-clean environments necessary for semiconductor work). In the new facility, sensitive LSI equipment could be used for research and development, applications could be developed, and devices used by other laboratories could be tested, calibrated, and monitored. The term LSI was coined to characterize the process that enabled computer chip manufacturers to put ever-more transistors on a single chip.[97]

Initially established to handle 50-millimeter-diameter silicon wafers with 3.0-micron minimum feature size, the complementary-metal-oxide-semiconductor (CMOS) facility for integrated circuit fabrication would be upgraded over several decades to 100-millimeter-diameter wafer processing capability. While maintaining expertise in CMOS technology, the facility staff would expand its capabilities to the development of Silicon-on-Sapphire (SOS) circuitry with minimum features of 1.2 micron.[98]

[95] *Calendar*, December 4, 1970, 4-5; the article was based essentially on the press release.
[96] NELC *Calendar*, January 28, 1972.
[97] On August 14, 1970, *Calendar* reprinted a *Wall Street Journal* article quoting Bob Graham, marketing manager of two-year-old Intel, as saying that within a few years "you'll see a 4,000-transistor chip…." Today (2015), Intel's Xeon processor contains 5.5 billion transistors. It was at about this time that Gordon Moore of Intel postulated "Moore's Law," the remarkably durable observation that chip makers double the power of their products about every eighteen to twenty-four months.
[98] Naval Ocean Systems Center *Outlook*, April 6, 1984, 1, and see Volume II.

ASDEC

Lack of facilities was identified earlier as a major challenge to a number of NELC project managers. The hope of a MILCON was perhaps reasonable, but even if that occurred the actual building was years in the future. On the other hand, a somewhat immediate solution was already in place. The Applied Systems Development and Evaluation Center (ASDEC), located in Building 33, provided developmental equipment that could be used by Center projects working to meet fleet operational needs.

A *Calendar* article about the facility reported,

> ASDEC allows the installation and evaluation of command control systems in an environment similar to that aboard ship. Programmed inputs simulate operational conditions and allow system capabilities and compatibilities to be refined prior to introducing a system aboard ship.[99]

The facility's equipment included an AN/UYK-7 computer, five CP-642 computers, an AN/UYK-4 display system, plus digital data links and live voice links. The UYK-7 was the follow-on to the 642s, and was the state-of-the-art shipboard system at the time. As discussed above, NELC had purchased one in the summer of 1971, the first Navy lab to do so.[100] The other systems in use, about twenty in number, were all tied to specific projects. Since the UYK-7 was selected as the "future follow-on shipboard system for all new command control tasks," NELC made it available to any project for which it was suitable.

Varying recruitment strategies

As described in earlier chapters, the weapons/undersea center organizations (NOTS, NUWC, NURDC, NUC) sponsored an enviable program for finding and recruiting exceptional science and engineering graduates and molding them into solid Navy technologists. The electronics laboratory approached it in a somewhat different manner, participating in Navy and State of California programs that combined academics with actual work experience.

---

[99] "ASDEC facilities save time, money," NELC *Calendar*, September 28, 1973, 2.
[100] NELC *Calendar*, August 13, 1971, 1.

Beginning in 1956, NEL participated in the Navy Science Engineering Co-Op Program.[101] Under that program, high school graduates with substantial technical interests and promising academic achievements were selected for a five-year commitment that included four nine-month academic years at a college/university, interspersed with twenty-four months employment at a Navy laboratory, including one academic year spent as a full-time lab employee. The Navy paid all tuition, lab expenses, and books for two of the four years spent at the university. If the student accepted the financial aid, he/she was required to work at the lab one month for every month of class attendance funded by that aid.

Another co-op program existed at NEL, in which science and engineering students already attending universities were recruited prior to graduation. Long-time Center technologist in and manager of sonar development, Morris Akers, was involved in an apprentice development program at North Island Naval Air Station, which provided participants a two-year college education with on-the-job training. After deciding to pursue a four-year physics degree, he was in his first semester at San Diego State when a recruiter from NEL, where he had worked occasionally, arrived to interview students. Akers jumped at the offered opportunity:

> Division head John Hickman said, 'If you'll come to work at the laboratory, we will essentially pay for your tuition, you can work up to twenty hours a week, and we'll work around your schedule.'…I was hired on a full-time basis as a physicist into NEL, Bayside.[102]

Science Achievement Club

NEL promoted general science education and careers. Several of the first *Calendars* advertised the lab's Science Achievement Club,

> an organization formed primarily for the purpose of carrying through each year the long-established NELEA Science Achievement Award Program at this laboratory, and for aiding and encouraging students of the San Diego community.[103]

Senior managers were elected as officers of the club, which sponsored a

---

[101] NEL *Calendar*, June 29, 1962.
[102] Morris Akers SSC Pacific oral history interview conducted by Tom LaPuzza, February 7, 2013, 2.
[103] "SAC Opens Membership For Brief Period," NEL *Calendar*, 8 and 22 January 1960, 1. NELEA was a State of California-sanctioned nonprofit organization.

science exam, as well as a technical writing competition, with ceremonies at which trophies and cash awards were presented to students and their high schools. A perpetual trophy named in honor of Dr. Gilbert Curl, a noted Point Loma Navy scientist, was presented to the school whose students scored highest in the exam.[104]

The Point Loma electronics laboratory took advantage of San Diego City Schools initiatives as well, including the annual science fair. Both NEL/NELC and the undersea center contributed large numbers of technical personnel to serve as judges for the competitions, plus fair competitors who were the sons and daughters of Navy lab technologists. The city schools' Exploratory Work Experience Program brought a number of high school students to NEL for an hour or so daily to work with lab employees on Navy technology development programs.[105]

The "real" future of the laboratories

Both NELC and NUWC/NUC continued to address their "real" future during the 1970s: the young scientists and engineers who would learn the philosophy and realities of Navy R&D and, adding that to their own substantial (but still academic) technical expertise, would push the technologies required by the Navy in coming decades. NUWC made an unfortunate but short-lived decision to discontinue its long-standing, highly successful New Professional program in Fiscal Year 1969, due to funding challenges. That lasted only a year, when the need to bolster technical staff stimulated renewal of the program, continuing to the present (2020).

NELC had sponsored a fairly different program for its newly recruited technical personnel, who voiced their concerns about its shortcomings in 1975:

---

[104] Dr. Curl arrived at the Navy Electronics Laboratory in August 1946, nine months after its establishment, advancing not only in his scientific career but also in management. As head of the Ocean Sciences Department, he was one of several hundred employees transferring in the 1967 reorganization to the Naval Undersea Warfare Center, where Dr. McLean gave him an identical title and position. He passed away suddenly the following April. (See April 19, 1968 issues of NELC *Calendar* and NUWC *Seascope*.) The concept of a memorial award surfaced spontaneously among his fellow scientists, who held him in high esteem. The undersea center subsequently named its primary science award for him. (NURDC *Seascope*, April 2, 1971, 1).

[105] "High School Students Learn As They Work At NEL," NEL *Calendar*, January 27, 1967, 3.

> Non-fulfillment of job expectations is a common complaint among NELC's junior professionals, according to the most recent personnel study group. Causes of dissatisfaction include recruitment and orientation methods which, the group said, could be alleviated by a program similar to that for new professionals at NUC. There, such employes [sic] participate in tasks across three codes in order to better evaluate potential jobs and choose the position with greatest opportunity.[106]

When the two labs merged two years later, the NUC program, which had originated in 1948, was adopted by the combined Naval Ocean Systems Center, providing new college recruits multiple-tour opportunities to explore several organizational units and work environments before final job assignment.

Case for consolidation, alignments made

In early 1976, the Navy conducted a study of seventy-four potential realignments, reductions, and base closures, determining if those were pursued it could save $56 million a year and send more than two thousand military personnel back to the fleet.[107] Independent of that study, although almost certainly aware of it, NELC personnel had met with their NUC counterparts down on the waterfront by way of a good-faith effort at consolidating some functions that were common and had identical rules, such as contracting. Requests were made to higher authority for such consolidations, undoubtedly with a sense of accomplishment. As will be discussed at the end of the next chapter, the Navy's need to save operating expenses required *major* consolidations, and the two laboratories on Point Loma, as different as they were, seemed ideal candidates for such an action.

---

[106] Junior professionals ask change in orientation methods," *Calendar*, February 28, 1975, 2.

[107] Navy announces study of NELC-NUC consolidation," NELC *Calendar*, March 26, 1976. The NUC *Seascope* story was identical, with a slightly different headline.

Robin and Dr. George

Between them, the Dillards—Robin and Dr. George—contributed more than eight decades of service to the federal government, almost all at what he once characterized as "the Navy lab on Point Loma with so many names." In fact, the only non-Navy lab years were the four George spent as a sailor in the early 1950s, during which he participated in "the first hydrogen bomb test" at Eniwetok Atoll. Following his military service, he attended San Diego State College from 1955 to 1959, and was hired by the Navy Electronics Laboratory as a research mathematician in the Radar Division.

Robin A. Worley had arrived at NEL a year earlier, also employed as a research mathematician in the Radar Division, after earning an A.B. degree, also from San Diego State. She spent most of her first decade applying statistical techniques to radar signal detection. Her pioneering research into sequential detection sought to optimize radar system performance. Based on her studies, she wrote a foundational paper titled "Optimum Thresholds for Binary Integration."[108] In it she discussed "a testing procedure that has received considerable attention in the literature… as a method of detecting signals in noise." Much of her research involved that quest for meaningful information in the midst of chaos. Her work on binomial sequential testing included development of a table of statistics applicable to radar testing, also valuable for agricultural and medical testing.

In the midst of decades sharing an office, Robin and George married in 1969.

Robin spent several years studying "the problem of intercepting friendly and unfriendly transmissions of energy," applying mathematical and statistical theory to the field of communications. Her dozen years studying signal processing theory resulted in her selection for the NELC Honorary Woman's Award in 1970.

Her paper "Detectability of Spread-Spectrum Signals" on covert communications was published in the July 1979 issue of IEEE's *Transactions of Aerospace and Electronic Systems Society* (AESS). It earned her the Mimno

[108] R.A. Worley, IEEE *Transactions on Information Theory*, March 1968.

Award, established "to recognize and foster excellence in clear communication of technical material of widespread interest to AESS members." That was just the beginning of awards, as she received the Navy's third highest, the Meritorious Civilian Service, for her work in radar signal detection techniques, spread-spectrum communications, and artificial intelligence technology.

Shortly thereafter, she served on the Command Action Team (CAT). Design and installation of CAT on USS *Carl Vinson* (CVN-70) "represents the first operational use of an expert system in a tactical environment by any of the three major services," according to a NOSC *Outlook* article (January 27, 1987). Robin "played a major role in performing the initial foundation work on the CAT project and also developing numerous mathematical algorithms that were incorporated as part of the CAT software." The project earned the team the Navy Award of Merit for Group Achievement.

Several years before retirement, Robin and Dr. George collaborated on a book with the same title as her 1979 paper, *Detectability of Spread Spectrum Signals*. The book collaboration was not a new thing: he also worked extensively in detection theory applied to radar systems, employing sequential analysis.

George was selected for long-term training, earning a Ph.D. in information and computer science from the University of California San Diego in 1971. The following spring, he received the NELC Honorary Award in Science "for his significant contributions to signal detection and systems."[109] Specifically noted was his devising "procedures for performing exact computations of the statistics of sequential detectors," replacing "inaccurate approximation methods that were previously the only methods available."

With the 1977 merger of NELC and NUC, Dr. George became an advisor to the New Professional program. He said in his retirement story that he "considers my involvement as an advisor in the NP program to be my most rewarding activity during my career at NOSC."

He transferred to the Surveillance Department in 1983 and worked on radar-related projects, including detection of sea-skimming missiles and development of radar anti-jam techniques. From 1984 until 1990, he was the U.S national leader of The Technical Cooperation Program (TTCP) Technical Panel KTP-3, the signal processing panel for radar technology.

[109] "NELC's highest honors accorded," NELC *Calendar*, April 14, 1972, 1.

In 1989, George agreed to spend half time in the Center's Research and Technology Office, evaluating Independent Research (IR) proposals, administering the Emeriti program, and working on the summer university faculty program.

In January and November 1991, respectively, George and Robin retired, with George's article stating he was returning as a Center re-employed annuitant. Not to be outdone, Robin's retirement article said she would continue her research into spread-spectrum detection as an emeritus. Based on her study of artificial intelligence and decision theory, her article "Using Data Quality Measures in Decision-Making Algorithms" was published in IEEE *Expert*.

As a re-employed annuitant, George continued his work in the Office of Research and Technology until 2005, at which time he had fifty years' federal service and retired for good.

Congratulations were in order for the Dillards, as Captain M.D. Van Orden presented Robin NELC's Honorary Woman's Award in 1970 and Dr. John Slaughter presented a patent award to Dr. George in 1974.

14

Gathering Forces on Point Loma

The Navy's 1967 laboratory reorganization provided some challenging but valuable opportunities for the staffs of those labs involved. For the Naval Command Control Communications Laboratory Center (soon to be the self-proclaimed Naval Electronics Laboratory Center, although that would not occur officially for nine months or so), emphasis could now be given to the work in communications, particularly for surface ships employing satellites, and to the information processing and electronics displays critical to command and control. The several hundred personnel involved in oceanography, submarine operational support, and similar undersea-related projects, most of them positioned geographically at the waterfront several miles from the headquarters, were now assigned to a Navy laboratory where they would be perhaps a better fit.

Similarly, the "Pasadena Annex," substantially removed geographically from its desert headquarters and representing undersea weaponry while the majority of China Lake personnel developed weapons deployed from or into the air, had been removed from a relationship with its former headquarters that both often considered strained. (Despite the severing of command structures, China Lake would continue to provide Pasadena with support services for some months to come, including ongoing coverage in the command newspaper, *Rocketeer*. Beginning in 1962, the newspaper featured about half a page of Pasadena news, and then a full page when *Rocketeer* went to an eight-page format. For nearly a year after the 1967 reorganization, most *Rocketeers* included a page devoted to "Naval Undersea Warfare Center.")

And the Naval Undersea Warfare Center organization had been provided accomplished technical personnel and numerous projects fitting precisely into its new title and descriptor.[1]

---

[1] As stated in the previous chapter, but repeated here where it is more significant, "Naval Undersea Warfare Center" describes the 1967 organization joining a technical directorate of the Point Loma electronics lab with the Pasadena undersea weapons organization.

To a substantial degree, Dr. William B. McLean got in NUWC the ASW lab he'd promoted for years, or at least the raw materials for it: the underwater acoustics/sonar experts from San Diego to find the targets, and the undersea weapons experts from Pasadena to destroy those targets. His major challenge was the integration of those experts and those technologies into a unified organization.

NUWC organization takes shape

He began that effort by selecting Doug Wilcox as his deputy for engineering and Dr. Don Wilson, the senior civilian of the new laboratory in San Diego, deputy for research. Pasadena division heads Charles G. Beatty, James H. Jennison, and DeVirl A. Kunz were elevated to department head positions, as were Don Cozen and A.J. Tickner. In San Diego, senior managers who transferred from the former Navy Electronics Laboratory Underseas Technology Department—Dr. Dan Andrews, Dr. Gilbert Curl, and Dr. Curtis Haupt—were designated as department heads as well. Dr. Curl would pass away unexpectedly in the spring of 1968, and be replaced, initially in an acting capacity, by George Anderson.

Recognizing the inevitable, or perhaps fed up with the perennial problem of inadequate facilities in Pasadena, early in 1968 NUWC Commander Captain Grady Lowe wrote his superior, the Chief of Naval Material (CNM), advocating placement of his headquarters in San Diego.[2] As Don Wilson had stated in his discussions with the Congressional subcommittee investigating the "big Navy" plan for an ASW lab at NAS Los Alamitos, the "headquarters" of the lab basically could be anywhere. Seemingly the plan was for a token HQ with a small staff, while the majority of the actual project work, and the support staff for it, continued in Pasadena, where about eighty to ninety percent of the workforce was assigned.

Captain Lowe's letter to CNM had stated his employees in San Diego received approximately two hundred work years of support from their former organization, now the Naval Electronics Laboratory Center (NELC). In response, one of those copied on Captain Lowe's letter, NELC commander Captain W.R. Boehm, had written to the CNM, also his superior, expressing apparent surprise at that number ("nor has this requirement been made known to NELC") but also

[2] Commander NUWC Pasadena letter, Serial 28, of 5 January 1968.

substantial willingness to provide that support. In his letter he observed that

> Paragraph 4 of reference (a) [Captain Lowe's letter] states that NUWC plans to operate the Center from the San Diego headquarters with only a nucleus of headquarters' staff and administrative facilities, which implies that the majority of the staff (administrative, service, and support functions) will be established or remain at NUWC Pasadena."[3]

Captain Boehm made a strong case for NELC offering its "considerable support establishment" to the new neighbor, thereby avoiding duplication of support and service functions and assuring utilization of precious ceiling points for the basic mission role of research and development activity.

He provided substantial evidence of his center's capabilities, citing among half a dozen organizations the ongoing support of the Personnel Research Activity and the Fleet ASW School. He also advocated strongly for NELC's retaining title to "Class 1 and Class 2 property" (basically land and buildings) and to the boats and small craft and the sailors operating them. His theme throughout, expressed in solicitous language, was ensuring the lowest cost for things and saving NUWC from having to invest in a lot of infrastructure he already had readily available.

Shortly thereafter, the Chief of Naval Operations ordered the move of the Naval Undersea Warfare Center to San Diego, effective July 1, 1968.[4] Although the OPNAV note made no mention of the Pasadena facility and its personnel moving south, it was not unreasonable to suppose the headquarters move order was unsettling to Pasadena employees, many of whom had deep ties in the numerous communities within commuting distance of the lab on east Foothill Boulevard. Twelve months earlier, the congressional subcommittee investigating the proposed facility at NAS Los Alamitos had visited the Pasadena facility to discuss that proposal, and Bill McLean, NUWC technical director for less than two weeks at the time, had argued against moving his new San Diego employees to the naval air station. When one of the congressmen, however, suggested he was making a case for moving the entire organization to San Diego, McLean had responded, "If you would like to consolidate at the same time."

McLean, seemingly always substantially ahead of the power curve, had proposed nearly a decade earlier the establishment of an ASW development entity on Point Loma, co-located with the Navy's electronics laboratory there. Dr. Don Wilson, who had been transferred from NEL to NUWC in the 1967

[3] Commander, NELC letter 7050, Ser 1000-6 of 26 Jan 1968, to Chief of Naval Material.
[4] Office of Chief of Naval Operations Note 5450, 26 June 1968.

reorganization, had told the same congressional subcommittee that the fleet was in San Diego, and thus it was a reasonable location for NUWC, given its mission. Certainly, the move of NUWC headquarters to Point Loma was the correct decision. Even the most die-hard Pasadena employees would have had to admit their facility presented a difficult challenge for a new and upcoming Navy lab organization, with its outdated physical plant and no room for growth.

On the other hand, scores of acres of open real estate, almost all of it under Navy control, waited patiently on Point Loma for new settlers to arrive. And those included Bill McLean with a handful of management personnel who had worked for him previously at China Lake and who for a variety of reasons elected to move south with their leader. Several of them would be key advisers to the technical director as he worked what he would later characterize as his greatest challenge: fashioning an effective single organization from two fairly different ones.

Facilities challenge

Perhaps most critical initially for McLean and his headquarters staff, the Naval Undersea Warfare Center, like NELC, experienced facilities shortcomings. Although higher Navy authority, upon directing NUWC to move its headquarters to San Diego, transferred thirty-five acres of NELC property on and near the waterfront to the undersea center, those acres held only a couple of moderate-size buildings and a number of small ones. Buildings 106 and 128, World War II-era former barracks, boasted two stories and a reasonable amount of office and lab space for the former NEL ocean scientists who worked there (with little room for additional tenants). Most of the smaller buildings had once been part of the turn-of-the-century quarantine station, which will be discussed directly: Building 101, which was the first NUWC San Diego headquarters; 112, which initially housed former NELC scientists conducting oceanographic research, but would later provide ashore office space for military operators of the Navy boats assigned to the command; and 115, which at a later date would become the Center's mail room. At an even later date it would be demolished to prevent interference with the extensive root system of the Moreton Bay fig tree flourishing overhead.[5]

[5] The NEL Station Journal in a 17 March 1952 entry lists the quarantine station buildings as 101, 102, 114, 115, 117, 118, 119, 121, 123, "returned to the Laboratory" on that date.

Addressing the subject of the fig tree: *Ficus macrophylla* is the scientific name of the Moreton Bay fig, also known as the Australian banyan; it is native to that continent. A huge specimen of it was located in the waterfront area transferred from NELC to NUWC. Located about fifty yards from the waters of San Diego harbor itself, the tree's remarkable height and lateral expanse dwarfed nearby buildings. An early NUWC *Seascope* (September 20, 1968) featured a pair of photos of the tree, accompanied by a caption stating it was protected by an act of Congress, passed on a September 1908 recommendation by President Theodore Roosevelt. Despite an impressive interpretative sign under the tree and the testimony of the superintendent of Cabrillo National Monument on the subject, a determined search by a Ph.D. historian working at the Center in the 1980s failed to locate any evidence of such a protective document. Nevertheless, the lab's facilities office provided the exceptional care it deserved and required over the decades, including, as stated, razing a building threatening its root structure.

Also included in the real estate deal of NELC-administered land transferred to the undersea center were Quarters L, assigned as the official residence of the NUWC commander, plus the Submarine Research Facility and Transducer Evaluation Center on top of the hill, fairly close to the NELC headquarters area.

NELC Waterfront Area turned over to NUWC, which included only two major buildings, Bldg. 106 (foreground center) and 128 (left foreground), and Quarters L (left center).

Interesting history

Those thirty-five acres immediately adjacent to San Diego harbor had interesting histories, based on two historical circumstances: the first was commemorated by a plaque in the middle of a lawn near the main pier complex where the Center's patrol escort ships and the submarine USS *Baya* tied up. (Along with the land and buildings, the surface and undersea craft of NELC were transferred to NUWC, despite Captain Boehm's suggestion his lab maintain control of them.) The plaque, mounted on a cubic-foot concrete base, was placed in 1934 by the Girl Scouts, proclaiming this as the spot the Stars and Stripes were flown for the first time, decades before California became a state.

There is a curious story behind that plaque, related in some detail in issues of the NUC and Naval Ocean Systems Center newspapers.[6] Summarizing, the area occupied today by the Center's various docks and waterfront buildings had been the site in the first half of the nineteenth century of a number of "hide houses." Numerous *ranchos* up and down the coast, still part of Mexico at the time, raised cattle for beef and their hides. American vessels plied the coastal waters, collecting hides and bringing them to the area, called *La Playa*, where they were treated and dried and stored in structures titled hide houses pending shipment via sailing vessel to the East Coast.[7] When a coastal collection ship arrived with a load of hides, several sailors were put ashore to cure them while their ship returned up the coast for more. In 1829, two of those thus selected were James P. Arthur and George W. Greene, from the merchant ship *Brookline*.

According to the *Outlook* article,

> It was a lonely life between ship visits, and one Sunday Arthur and Greene fashioned a flag to wave at passing ships, hoping to attract the attention of an American vessel and thus have a little company. Their flag had 15 red and white stripes and 24 stars, with the material coming from Greene's blue calico shirt and Arthur's white linen and red flannel shirts.

The "shirt-tail flag" fluttered over a hide house briefly, until the region's Mexican governor arrived and ordered it taken down, considering it insulting to

---

[6] "Girl Scouts Present Flag At Quarters M," NUC *Seascope*, June 4, 1976, 1, and "Plaque at NOSC commemorates first flag raising in California," NOSC *Outlook*, June 1, 1979, 3.
[7] An excellent detailed description of the area and the hide collection and drying process appears in Richard Henry Dana's *Two Years Before the Mast* (New York: Penguin Books, 1964). See also Appendix D.

his hospitality of the Americans and a defiance of his authority. It was lowered immediately.

The article continues that the San Diego Historical Society commemorated the event by planting a eucalyptus tree on the site of the hide house, and the following year the Girl Scouts placed the marker. The latter still rests on the lawn of Building 190, which the Center renovated into a recreational site titled the Dolphin Facility many decades later.

Quarantine station

The other historical event occurred in 1888, when the U.S. Treasury Department established a quarantine station on the bay, of which Building 190 was a part.[8] Buildings were erected beginning in 1891, a number actually constructed on piers, in addition to those at what became the NEL/NUWC waterfront area.

In the early 1900s, the San Diego Chamber of Commerce sought to attract the Navy to establish a presence in the city. The first successful result was a coaling station, established in 1904 and including a pier and adjacent coal storage areas on land. Eventually that area became what is today the Naval Supply Center re-fueling pier, located a short distance from the southern edge of the current Navy laboratory property.

At the time of original establishment, however, that land was occupied by the quarantine station. Its specific features—gently sloping beach with an area for a pier that could extend the relatively short distance to deep water where sea-going ships could dock—rendered it a perfect location both for the Navy to operate a coaling station and the Treasury Department's Marine Hospital Service to examine and, if necessary, quarantine immigrants with health issues that might endanger the country's citizens. Ultimately, the Navy won out: the Fort Rosecrans military reservation set aside a large portion of former quarantine station grounds for Navy use; the Marine Hospital and the quarantine station moved out. As of 2020, when it was heavily involved in the COVID-19 pandemic, the quarantine station office was on Rosecrans Street about four miles north of the now huge

[8] Appendix D provides more detail on the hide houses (above) and information on the quarantine station and the Marine Hospital, which is summarized below.

Navy complex on Point Loma that included Naval Information Warfare Center (NIWC) Pacific. The NIWC Old Town complex was less than a mile from the quarantine station office.

New headquarters building and new name

The scattering of buildings near the bay transferred to NUWC was already the regular working area of many of the former NEL employees now assigned to the new laboratory, although a number of acousticians transferred to NUWC remained in place in NEL/NELC buildings in the headquarters area around Building 33. With the move of NUWC headquarters to San Diego, the immediate key concern was creating reasonable office space for its management personnel to set up a command structure and develop the appropriate rules and regulations and procedures necessary for a major Navy laboratory. Early in the new year of 1969, Center commander Captain Grady Lowe, supported by Assistant TD for San Diego, Dr. Don Wilson, cut the traditional ribbon dedicating the new headquarters

Building 173T was the first new structure in the Waterfront Area after NUWC's arrival, serving as its headquarters. The "T" (for "temporary") was questionable, since the building still serves the Point Loma laboratory more than 50 years later.

facility of the Naval Undersea Warfare Center.[9] Building 173T was an improvement on the old Building 101, but it was in fact a rather small, prefabricated building, originally leased from a contractor and then purchased outright in 1971. It was clearly intended as a temporary home for top management.[10] (The "T" suggested the building would be replaced sooner rather than later, although half a century later it would still be in use).

In the ceremonial photo of the building opening, a tall, distinguished-looking naval officer is immediately behind Lowe; Captain Charles B. Bishop had reported aboard as the prospective Center commander and was shadowing Lowe to become accustomed to something fairly unusual for him: a command that wasn't at sea. Two weeks later, on February 7, 1969, Bishop and Lowe exchanged the customary change-of-command salutes, and Captain Lowe returned to Pasadena to serve

Captain Charles B. Bishop (right) relieves Captain Grady Lowe as commander, Naval Undersea Warfare Center. Captain Lowe would become Pasadena officer-in-charge.

[9] NUWC *Seascope*, January 24, 1969, 1.
[10] Naval Undersea Research and Development Center Command History, 1 July 1969 through 30 June 1971, 30.

several more months as officer-in-charge before he was finally able to retire. The Navy had already recognized his leadership achievements in September 1967, when he was awarded the Legion of Merit for "serving successively as OIC, Pasadena; Commander, NOTS; and concurrently as Commander, NWC and Commander, NUWC."[11] For the new Center commander, things began moving quickly, and not always to his liking. A seasoned submarine veteran of World War II, with lengthy experience commanding warfighters in combat and receiving grateful, and reasonable, public acknowledgement of his service, Captain Bishop now headed a laboratory whose very name incited, in the anti-war late 1960s, substantial public disapproval. His recruiters, significantly successful at bringing remarkably talented young engineers and scientists aboard to replace aging technical personnel dating back to that world war, found themselves *persona non grata* when they mentioned the organization they represented was a "warfare center." The needed re-supply of new talent was drying up, at a fairly critical time in the early months of the new organization.

Less than two months after the Lowe-Bishop change of command, the Navy dealt with that issue by renaming the organization the Naval Undersea Research and Development Center (NURDC). The Center newspaper made a statement about emphasizing the R&D mission,[12] and in actuality that seemed to work for the recruiters, even though the majority of the R&D they were pursuing had to do with, and continued to be, weapons development.

Not everyone applauded the new title. In an interview two decades later, Captain Bishop revealed that name had presented him personal difficulties almost immediately; it would take most of his three-year tour at the lab to get it changed: "So they went to this NURDC. Well, I couldn't stand [it]; I told people I am not going to be the head of a bunch of nerds!" One suspects he mentally spelled it "a bunch of NURDs."[13]

A discussion follows below about the "dual executive" principle and relationship, but one pertinent point can be made here: among the generally accepted responsibilities of the military officer in that relationship is the physical plant: the grounds, facilities, and structures that house personnel, regardless of what work they are directed to pursue. Captain Bishop, in relieving Grady Lowe,

[11] NUWC Command History, 1967, iv.
[12] NURDC *Seascope*, April 4, 1969, 1.
[13] Captain Charles B. Bishop, USN (Retired) interview conducted by Dr. Mark Jacobsen, October 1987, 12.

also inherited his challenges of providing adequate physical facilities for lab personnel, which were increasing in numbers through recruitment of new staff members and increasing transfers of personnel from Pasadena.

Fortunately, in December 1970, as part of the Fiscal Year 1971 Military Construction bill, funding was approved for construction of a laboratory/administration building: $6,736,000 for a five-level structure of more than 150,000 square feet. The Center newspaper reported: Of the 500 personnel to occupy the building, about 280 are now in trailers, old buildings scheduled for demolition at NELC and Naval Supply Center on Point Loma, and temporary structures at NUC San Diego.[14]

Eight months later, groundbreaking ceremonies were held. Rather than the traditional shovels in a row already noted several times, or the unusual tree-planting that would occur at NELC in three years for its new electronics lab, the unique ceremony featured the eminent physicist Dr. William B. McLean in a hard hat at the controls of a bulldozer, knocking down a condemned building on the construction site. Captain Bishop half-stood and half-sat on one of the shoes of his

An unusual groundbreaking for the undersea center's Building 1 featured Dr. William B. McLean using a bulldozer to destroy an abandoned structure on the site. Center commander Captain Charles Bishop could only hold on.

[14] NURDC *Seascope*, December 18, 1970, 3.

Navy whites on the operator's seat next to McLean, who repeatedly lunged the 'dozer at the tottering building. In the midst of it all, a spark set the tinder-dry structure on fire, and the ceremony closed in a cloud of smoke and the sound of sirens from NELC Fire Department trucks speeding to the scene. (An interesting construction juxtaposition: The ceremony marking the beginning of construction of the laboratory building in San Diego occurred August 2, 1971. Less than three weeks later, on August 20, groundbreaking ceremonies were held at the NURDC Pasadena Lab for a new building to replace the machine shop, scheduled for demolition to make way for the Interstate 210/Foothill Freeway. Less than three weeks apart in May 1974, the San Diego building was formally dedicated, and the Pasadena Lab, its new machine shop recently dedicated, was formally disestablished.)

Dr. McLean and Captain Bishop also represented an interesting juxtaposition, and not just on a bulldozer. Bishop, a December 1941 graduate of the Naval Academy (with Isaac Kidd, Jr., who later as Chief of Naval Material would be his immediate superior in command), had decided opinions about the meaning of command, ashore as well as at sea. In the latter, he had commanded no less than three submarines, a destroyer, and an attack transport, plus an amphibious squadron and an amphibious ready group in combat operations off Vietnam, for which he received the Legion of Merit and the Vietnamese Navy Commendation Medal. (His submarine commands included USS *Baya* in the mid-1950s, when the submarine was assigned to NEL to participate in sonar experiments.) With a degree in electronic engineering from the Naval Postgraduate School and a master's in applied physics from UCLA, he considered himself, when an interviewer called him "technically adept," rather "technically exposed."[15]

Repeatedly acknowledging the brilliance of McLean in the interview (telling a story, for example, about McLean's solving a significant problem with the Army's main battle tank, not because he knew anything about the Army or tanks, but because "he is a scientist. And he is a top-flight scientist, an engineer"), Bishop nevertheless considered it necessary to rein in that scientist's sometimes headlong pursuit of an objective, regardless of the methodology. Two areas in particular were sources of potential friction.

---

[15] Captain Bishop interview, 9.

Designated funds "borrowing"

The first was McLean's well-known penchant for "borrowing" funds from one source to bankroll another for which it was not intended. (Perhaps unknown to him, that was exactly how commanders of the Navy bureaus, and their successor systems commands, did business.) Bishop had seen that before his undea center tour, when he crossed swords with McLean about the *Moray* submersible:

> Diverting money was exactly where the nature of the game was. I was the guy responsible for seeing that that money got spent the way the submarine folks wanted it… And here comes Bill McLean and he would come in through the secretary's [of the Navy] office and get some of that money carved off for his *Moray* project. So we had a battle going on, a once-a-year hassle over this," despite the fact "I never met him personally until the third year of that tour of duty.[16]

Equally frustrating to the naval officer with a strict interpretation of the way things should be done was McLean's desire for control:

> He was always very interested in getting total system development responsibility for the laboratory… When you have to go into production with the kind of design that [is] required for production engineering, now you get into the high levels of reliability, maintainability and low mean-time-between-failure, and all these kinds of things. Well, that is a whole world of itself the big military-industrial contractors are familiar with… it is industrial engineering. That is a long way from the development side. You don't want to mix those things. You start getting development mixed in here, you have got a floating disaster. And we do every year… You have got to keep them separate. Well, Bill didn't believe that.[17]

If Bishop disagreed with McLean in principle, he did not on the scientist's ultimate purpose: getting high-quality products into the fleet. The industrial partners Bishop cited were certainly a necessary part of the acquisition process, but as Vice Admiral Ashworth of the Bureau of Weapons had so pointedly observed (see Chapter 10), NUWC engineers knew more about their technology than the contractor could imagine. After all, they had spent countless hours designing it, putting it together, correcting their own errors, making it work well because they wanted it to work well. They were not driven by a profit motive, so if the device/system required an extra week of labor to perform well, they labored an

[16] Captain Bishop interview, 3.
[17] Captain Bishop interview, 4.

extra week. If it required three expensive braces instead of two to stabilize it on a destroyer pitching and rolling through heavy seas, they purchased another brace.

The "bottom line" for McLean and the people who worked for him was to place quality devices and systems into the hands of sailors, and they understood better than anyone how to do that. Captain Bishop would have accepted the first part of that statement early on in his tour at the Center, and by the end of it he would have agreed with the second part as well.

As there were differences, sometimes substantial, between the two men leading the same laboratory, there were also significant points of agreement. Discussing McLean's keen interest, technical as well as personal, in the underwater realm, Bishop said, "… he could see that the undersea world was really where the Navy of the future was going to have to go." McLean's own comment about this time was,

> In my mind, the first indication that the Navy intends to survive and win a limited-war conflict at sea using non-nuclear weapons will be when they start the research on submarine tankers and submarine transport. Without this capability I see no possibility for long-term survival of naval forces.[18]

According to Bishop, "… one of the first things that we got involved in after I got here, he and I got together… and we wrote this paper up on the subject of the need for the Navy to go undersea."[19] The two presented the paper to the Undersea Warfare Planning Council.

Mutual respect

And there was certainly mutual respect. As noted, Bishop extolled McLean's technical vision and accomplishments time after time. He also realized (consistent with protocol for a Navy change-of-command) that McLean would ensure everyone attending a meeting was in place in the room before inviting the captain in, and when Bishop entered, he would rise to his feet. "I was pretty impressed with the guy," Bishop said.

---

[18] William B. McLean, "Survival of the Navy at Sea" presentation, January 8, 1975, Collected Speeches of Dr. William B. McLean, 223.
[19] Bishop interview, 5.

That was a good thing, since despite his view of authority and where it ultimately resided, the second NUWC command history (a document required of every Navy organization for annual submission to the Chief of Naval Operations) included the sentence, on its first page: "Dr. Wm. B. McLean, Technical Director since Center establishment, is jointly responsible with the Commander for mission accomplishment and effective Center management."[20]

Dual executive

In Chapter 4, we discussed the early-day relationship of the senior military and civilian at the weapons laboratory in the desert. Captain Sherman Burroughs, first commanding officer of the Naval Ordnance Test Station, told his small cadre of military officers shortly after his arrival in December 1943: "… we have to use the brains of these professors to dream up solutions to our military problems. It is the job of all of us to see that these civilians get everything they need to do their jobs."

At the time, there was no senior civilian at Inyokern; in fact, there were no federal civilian employees assigned to the station at all. The "civilians" he referred to were professors from the California Institute of Technology. It would be months after the end of World War II before Dr. L.T.E. Thompson agreed to serve as director of research for NOTS. Thompson, faced with the unenviable task of recruiting top-level scientists and engineers to the desolate Mojave Desert, told his superiors he could not succeed at that task without a "charter." The Bureau of Ordnance chief, Rear Admiral George F. Hussey, agreed, asking him to write one, and asking the same of another of his subordinate organizations, the Naval Ordnance Laboratory (NOL).[21]

---

[20] NURDC Command History, 1 July 1969 through 30 June 1971, 1.

[21] Dr. Ralph Bennett was not only the NOL civilian technical lead but also a captain in the Naval Reserve, providing him exceptional credibility. In establishing the laboratory at White Oak, Maryland, he and his commanding officer forwarded to the BuOrd chief a statement of operating principles which was approved in early February 1947: "The principles emphasized that the civilians were in charge of the technical program and the military were there as advisors; that the support functions would report to the technical line, not the military one…" William B. Anspacher et al., *The Legacy of the White Oak Laboratory* (Dahlgren, Va.: Naval Surface Warfare Center, Dahlgren Division, 2000), 372.

As detailed in Chapter 5, Dr. Thompson developed, in response to Rear Admiral Hussey's request, the Naval Ordnance Test Station "Principles of Operation,"[22] which the NOTS commanding officer at the time, Captain James B. Sykes, declined to endorse. After the document rested on the captain's desk for months, Thompson wrote Rear Admiral Hussey, asking that his resignation be accepted. (Although the BuOrd chief agreed with substantial reluctance, Thompson did not follow through and stayed on for another five years.) Sykes eventually signed the letter with the "Principles" included and sent it to Hussey. The latter approved it October 21, 1946, and those principles became embedded in the China Lake operational philosophy.

In the meantime, the White Oak laboratory leadership continued to push for increased civilian authority, advancing the principle the "Commander and Technical Director are *jointly responsible* [emphasis in original] for the effective and economical internal functioning of the Laboratory."[23] Rear Admiral Hussey's successor at BuOrd approved it. In 1954, NOL's civilian lead Dr. Ralph Bennett advanced the cause even further, testifying before a congressional subcommittee on research and development management at the service laboratories.[24] Not only did he reiterate the CO/TD joint responsibility concept, but he also advocated a strong voice for the laboratories in the determination of reasonable and suitable subjects for research. The Secretary of the Navy endorsed both principles, which were incorporated into a SECNAV instruction.[25]

Eight years later, under pressure from the Department of Defense to strengthen the laboratories, the Navy secretariat reissued the instruction, now numbered 3900.13A and renamed "Management of Navy R&D Laboratories." Noteworthy about the new instruction was the fact it was based substantially on the "relatively stable and successful internal management relationships" existing at the Bureau of Ordnance laboratories (Naval Ordnance Test Station, China Lake, and Naval Ordnance Laboratory, White Oak, Maryland) and based on their "operating principles" discussed immediately above:

---

[22] J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California*, Volume 2, Appendix F.
[23] *The Legacy of the White Oak Laboratory*, 373.
[24] Subcommittee of the House of Representatives Committee on Government Operations, Organization and Administration of the Military Research and Development Programs. (Washington, D.C.: Government Printing Office, 1954).
[25] Secretary of the Navy Instruction 5450.3, Organization and Administration of Navy Research and Development Facilities, 21 April 1955.

> The significant feature of the Instruction was its endorsement of the dominant role of the technical director in the performance area, while reaffirming the overall management responsibility of the military commander. The key paragraph provided that 'the Commanding Officer will delegate line authority and assign responsibility to the Technical Director for the technical program, its planning, conduct, and staffing.'[26]

The policy was not universally accepted; in fact, one of the bureaus didn't even distribute the instruction to its laboratories. (Interestingly, the "policy" became the standard at the Navy labs, but in a military environment it often was not well understood. Carmela Keeney, who spent more years as the Point Loma lab's senior civilian than anyone except Bill McLean, experienced the fall-out when a senior officer reported without knowledge of "the policy": "Periodically a new flag officer or commanding officer comes in and challenges the joint leadership concept. It creates havoc for awhile and some bad decisions end up having to be undone."[27]

The White Oak history, published following the demise of the lab as the result of Base Closure and Realignment Commission actions of the 1990s, cited the NOTS China Lake "Principles of Operation" as being "from about the same time as WOL" (China Lake's were actually approved four or five months earlier), but claiming "WOL was given credit, or blame, as the generator and active champion of these 'operating principles' that were not in accord with traditional naval principles of command and which challenged the control of the military managing agencies."[28] The statement of "credit or blame" was unaccompanied by any examples or corroborating citation.

The Navy's electronics laboratory on Point Loma had a different take on the matter, employing a civilian chief scientist but vesting primary leadership in a military officer, a captain, whose title until the 1967 major reorganization of West Coast Navy labs was "commanding officer and director." As detailed in the previous chapter, that changed substantially in 1970, when NELC adopted a "joint chief executive" concept with the Center commander and technical director working closely together on an equal plane to "ensure close coordination of technical programs with total Center operations."[29]

---

[26] Department of the Navy, *Review of Navy R&D Management 1946-1973*, June 1, 1976, 142.
[27] Carmela Keeney email to Tom LaPuzza, November 1, 2019.
[28] *The Legacy of the White Oak Laboratory*, 374.
[29] NELC Annual Report 1970, 5.

Moving forward

According to the very first command history of the Naval Undersea Warfare Center:

> The basic organization of the Center was formed by combining the undersea warfare and ocean research elements of the Navy Electronics Laboratory (NEL) with the ASW and undersea technology and engineering elements of the Naval Ordnance Test Station (NOTS). By CNM letter MAT 031B:SR of 4 October 1967, the Marine Bio-science Facility of Point Mugu was included in the Center organization through transfer from the Naval Missile Center (NMC). NUWC has also established a new facility at Kaneohe Bay, Oahu, Hawaii, as an additional step in developing a comprehensive undersea program.[30]

The new Navy laboratory made good organizational progress toward development of that comprehensive program in its first several years of existence. Taking a hint from NOTS, which began publishing a newspaper within a few years of its establishment, NUWC appreciatively accepted coverage in the *Rocketeer* for eight months after the two labs separated, then launched its own newspaper, *Seascope,* on March 1, 1968. That first issue featured Captain Lowe and Dr. McLean on the cover and promised, "We plan also to feature our Center so that each group will know who the other groups are, what they do, and facilities of which they have cognizance."

A degree of familiarity already existed since the technical personnel had transferred from the electronics lab and those of the weapons organization had some knowledge of one another. From collaboration on the Mousetrap launcher to test ASW weapons during World War II, to Andreas Rechnitzer's presentation on work with the bathyscaph *Trieste* in the early 1960s, to the Integrated Combat System project review at NEL in the fall of 1965, there had been some amount of technical information exchange between the labs. It was, however, limited and disjointed, and often lacked context. What the *Seascope* editorial staff proposed was an organized introduction to senior personnel and significant projects and associated facilities of each of the new organization's departments. The objective was to acquaint two disparate sets of highly skilled technical personnel with one another. As McLean would say several years down the road, bringing together those two groups represented the organization's greatest challenge.

---

[30] Naval Undersea Warfare Center Command History, 1968, 2.

In addition to introducing Captain Lowe and Dr. McLean, that first newspaper also provided the assigned mission of NUWC: "To conduct a program of warfare analysis, research, development, test, evaluation, systems integration, and fleet engineering support in undersea warfare and ocean technology."

After issues featuring top management and the technical officers, the next seven *Seascopes* ran major stories on each department, including its top managers, a statement of assigned technical responsibilities, and some of its products. For example, the Ordnance Systems Department, headed by Chuck Beatty, "directs and conducts all phases of engineering, development and evaluation on underwater ordnance programs." And the Systems Technology Department, managed by A.J. Tickner, "plans and manages a program of research and development to advance basic knowledge in the technologies required in undersea warfare with emphasis on weapons, weapons systems, and their simulation."

One of the former NELC groups under Dr. Dan Andrews was assigned a somewhat more detailed responsibility: the Systems Development Department

> plans, manages, directs, and coordinates undersea warfare projects at the advanced and engineering development, and system support levels; conducts analytic environmental, system

The first NUWC Technical Board included (seated, l-r) George Coulter, Dr. Curtis Haupt, D.A. Kunz, Wallace C. Hicks, Captain Grady Lowe, D.J. Wilcox, Captain Charles B. Bishop, Dr. William McLean; (standing, l-r) Charles G. Beatty, A.J. Tickner, Don Cozen, George Anderson, Dr. Don Wilson, William Hampton, Jesse Burks, Bernard Silver, James Jennison, Dr. William D. Squire.

and operational modeling for performance prediction, system design and utilization and cost-effectiveness purposes; studies potential application of new concepts and techniques to undersea warfare needs.[31]

Several of the summer 1968 issues discussed the support departments—Public Works, personnel, Operations Department (the military), and Command Administration. They shared billing with a major-headline event: launch of the research and development submarine USS *Dolphin* (AGSS-555). Often called "the nickel boat" or "triple nickel," based on its hull number, the submarine would play a signal role in the undersea center's work on sonar development. After its single torpedo tube was replaced with an experimental sonar dome that added thirteen feet to its length, it arrived for the first time at the NUC pier November 7, 1970. Shortly after its arrival, a sonar suit designed by Center personnel was installed, and the boat departed for the Gulf of Alaska with USS *Baya* (AGSS-318) and the newly arrived oceanographic research ship USNS *S.P. Lee* (T-AG-192). The mission was to evaluate the improvement in sonar performance versus depth and to begin what would be a three-decade endeavor of the sub's civilian technical personnel to collect sea test data critical to sonar system operation.[32] All Center personnel involved in the Alaska cruise and the crews of the three vessels received the Navy Award of Merit for Group Achievement for the effort.[33]

Perturbations in the system

As the tumultuous 1960s, described in some detail in an earlier chapter, moved to an end, the tumult did not. Opposition to the war in Vietnam became increasingly strident, with the effect noted earlier of unwillingness of potential new employees to work at a "warfare center." In the spring of 1969, the Navy's solution, which changed absolutely nothing about the work pursued at the organization, was to modify the aggressive title to Naval Undersea Research and Development Center.[34]

---

[31] NUWC *Seascopes*, April 5, May 3, and April 19, 1968, respectively.

[32] Naval Undersea Research and Development Center Command History, 1 July 1969 through 30 June 1971, 5.

[33] Naval Undersea Center Command History, 1 July 1971 through 30 June 1972, 21.

[34] NURDC *Seascope*, April 4, 1969.

Early in 1970, despite increased success in recruiting, Center employees began discussing in hushed tones that most feared of all government practices: the reduction in force (RIF). Half a dozen issues of the newspaper published articles provided by management, relating the principles and complicated procedures that allowed some degree of "bumping" of employees in similar Civil Service job series (at an equal or lower level, and with less federal service) by individuals whose positions had been eliminated. Although the uniform formality of the Civil Service System of discrete job series seemed straightforward, "wrinkles" were possible. For example, when a high-level employee in a technical series had held a clerical position in Civil Service while attending college, he or she was allowed to "bump" clerical employees with less seniority. The flood of articles began with a message from Captain Bishop, advising the normal attrition rate appeared insufficient to reduce personnel numbers to the assigned ceiling. Thus, management had concluded a RIF was the only solution. Employees were told about priority placement, severance pay, and programs for displaced workers. Of course, what they weren't told, the only thing that actually mattered to any of them, was: "Is it me?" The number Captain Bishop provided was forty-eight, which was a relatively small number considering the employee workforce of approximately fourteen hundred.[35] It is next to impossible to ignore, however, the potential that one's job, and thus one's paycheck, might disappear.

Interestingly, it was a program established by higher authority, the origin of the ceiling limit stimulating the RIF, that prevented any lost paychecks. After months of front-page articles about job-loss actions, *Seascope* ran a small article on Page 3, noting the Center had been selected as one of ten Defense laboratories to participate in an experimental program titled Project REFLEX [sic].[36] The article reported REFLEX (which may have stood for something, but that was not explained) allowed the selected labs to "operate under fiscal controls instead of manpower ceilings." Historically a combination of the two determined employee numbers, but the experiment *mostly* eliminated the personnel aspect. "Mostly" reflects a statement suggesting personnel numbers would still be a factor. The one-sentence conclusion stated the new program did not change the requirement to meet assigned workforce ceiling. In a "Captain's Corner" column immediately

[35] Naval Undersea Research and Development Center Command History, 1 July 1969 through 30 June 1971: "NUC began with an allocation of 1300 full time permanent civilian billets and 301 military billets." Over the next few years, it would add several hundred civilian billets.
[36] NURDC *Seascope*, May 8, 1970, 3.

below the article, Captain Bishop cautioned operating under REFLEX did not allow unlimited hiring, but "hiring within the limits of program funding."

Another reorganization

While department managers were working to understand REFLEX and deciding to hire (or not) technical personnel, top management introduced yet another feared federal government practice already discussed a number of times: reorganization. NELC reorganized after several hundred employees, a number of projects, and several facilities were transferred to the undersea center in 1967, and again in early 1970. NUWC had established an initial organization covered in its first newspaper issues in 1968. It also, however, saw the need for reorganization, which was implemented in mid-1970:

> The ten existing departments were disestablished and the following six departments were established: Fleet Engineering, Weapons and Countermeasures, Computer Sciences and Engineering, Ocean Sciences, Sensor and Fire Control, Ocean Technology.[37]

One significant rationale for that was addressed by Captain Bishop in his post-retirement interview, advising Technical Director Bill McLean

> particularly wanted Howard Talkington to be his guy for leading the ocean engineering… Bud Kunz was… head of that group… and they had done a lot of good things… the Polaris work, the CURV [Cable-controlled Underwater Recovery Vehicle] work and all that kind of stuff. But Bud himself was not really a technical guy. Bud was a great people man, a great leader, a great recruiter. Boy, he really prepares people and he had a great organization. But Bill [McLean] could see that there was a need for a guy with a real technical capability, and Howard was that guy.

The several problems attendant on that desire included the fact Talkington worked for Kunz as one of his division heads; if leadership of ocean engineering work was handed off to Talkington, what was Kunz supposed to do? Bishop was unable to remember during his interview if the solution was a top management one, or if Kunz suggested it himself, but the decision was to establish a new department focused on fleet engineering, developing closer ties with fleet units and providing more short-term support with less acquisition system formality.

"Bud latched onto that right away," Captain Bishop reported.

---

[37] NURDC Command History, 1 July 1969 through 30 June 1971, 11.

Departments reduced

As a result of the reorganization, the ten departments that had rendered the Center somewhat top-heavy were reduced to six, with Talkington heading the Ocean Technology Department and Kunz managing the Fleet Engineering Department. (The other department heads were Chuck Beatty, Weapons; Bill Squire, Sensors and Fire Control; George Anderson, Ocean Sciences; and Jim Jennison, Computer Sciences and Engineering.)

A chart in the June 12, 1970 *Seascope* illustrated the new organization, described in the text as

> a matrix… in which the line departments will carry on technical programs in assigned functional areas. The systems program managers will pull together the elements of the programs associated with each of the systems areas for which we have responsibility, and will provide coordination…

The four managers listed were Barney Towle (the retired Navy captain who had championed establishment of the proposed ASW complex at Los Alamitos Naval Air Station), who was responsible for air systems; Roger Prager, surface systems; Shelby Sullivan, submarine systems; and Dr. Harry Schenck (listed as acting), surveillance systems.

Another critical decision in the reorganization was to develop an active intelligence program. In mid-June, the Intelligence and Planning Office was established "to conduct studies in pertinent intelligence areas, and to develop a planning system for evaluating NUC's current and future technical programs."[38] (An essential objective of intelligence gathering is determining military strengths and weaknesses of a known or potential enemy, in order to develop strategies and weapons to defeat or exploit those, respectively.)

In addition to the chart, a set of questions and answers in the same issue explained the reorganization to employees. Its stated purpose, in response to the first question, was "to provide additional capability for tackling problems, and better communications from management to the people carrying out the work." Lack of communication on the subject of the reorganization was also one of the questions, with a reasonable response that "Improvement in internal communications will be a major concern to our new department heads."

[38] NURDC Command History, 1 July 1969 through 30 June 1971, 11.

The Q&A article did answer a critical question on the minds of many: "NUC has no plans for reduction in force in the future. Project Reflex should protect us from percentage DOD cuts." Another such question was also answered positively: "No plans are being considered to transfer additional people from Pasadena."

(Again, based on their effort to improve communication and respond to continuing angst about personnel transfers, in late 1972 the fairly new NUC commander, Captain Robert H. Gautier, and Technical Director Dr. William McLean held two all-hands meetings in Pasadena: "In both Pasadena meetings, the critical question in most minds was the possibility of personnel moves to San Diego. Both Captain Gautier and Dr. McLean stressed that no plans of any kind have been made in anticipation of any move announcements," which they emphasized would only come from Congress.[39] In the meantime, a question at one of the meetings was met with the encouraging response, "The new 600-man laboratory for Pasadena Laboratory is planned to follow the construction of the 500-man San Diego Laboratory, in accordance with the approved OSD [Office of the Secretary of Defense] MILCON program plan." That response must have put the minds of many Pasadena employees at ease.)

Undersea surveillance role sought

In his post-retirement interview, Captain Bishop discussed the last of the 1970 reorganization Q&As, related to uncertainty over the new "NUC East Coast activity." The REFLEX article several months earlier had listed four Navy labs participating in the effort, with two of the others the Naval Underwater Weapons Research and Engineering Station in Newport, Rhode Island, and Naval Underwater Sound Laboratory in New London, Connecticut. Those with a keen memory will remember the underwater sound lab emerged shortly after World War II, as did NEL, as the successor organization to those contributing to the war effort and considered too important to be dismantled after the conflict. The New London lab was the Navy's follow-on organization to the Columbia University Division of War Research and the Harvard Underwater Sound Laboratory. (And, in fact, the title itself was a hold-over: as the University of California Division of War Research had been termed the "San Diego lab" of the Office of Scientific

[39] NUC *Seascope*, January 5, 1973, 2.

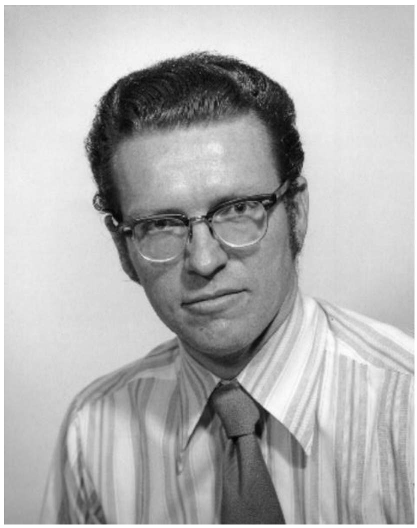
Research and Development during the war, the parallel Columbia University division had been termed the "New London lab" in many of the OSRD reports.)

Captain Bishop's stated concern was that the New London lab's "main backbone" was shipboard sonar. His own organization, and specifically the part transferred from NEL, was heavily involved in this technical area with such things as the PAIR (Performance And Integration Retrofit) improvement of the AN/SQQ-23, designed to provide significant improvements in ASW capabilities for a large number of Navy ships. (One number advanced was sixty-four ships; another was a hundred and fifty.) Acknowledging two Navy labs pursuing the same effort would result in "a horn-locking contest," Bishop asked, at a department review meeting, who was involved in undersea surveillance: "Before we break this meeting up I want a name." The name he was provided was Dr. Harry Schenck.

Dr. Harry Schenck

Harry Schenck began classes at Pomona College in east Los Angeles County as a physics student in 1956. During summers between academic years, he worked on FM sonars as a student trainee at the Navy Electronics Laboratory. With his degree in hand, he was scheduled to begin working full-time at NEL. Instead, he took leave without pay for five years and attended Harvard, earning his Ph.D. in

Dr. Harry Schenck



applied physics, specializing in acoustics. His adviser was the famed underwater acoustician Frederick V. Hunt, who, as discussed in the first chapter, headed the university's Underwater Sound Lab during World War II. Schenck returned to NEL in 1964 to develop models of piezoelectric transducers employed in undersea surveillance. He was transferred with several hundred associates to the new NUWC in 1967. Given his education and several years of experience, his was the logical name to be provided to Captain Bishop when he sought a manager for his proposed effort to establish a leadership role in undersea surveillance systems.

After a reasonable amount of in-house management discussion, Captain Bishop and Dr. McLean visited the Assistant Secretary of the Navy (R&D) and offered the lab as the Navy lead for undersea surveillance. There was substantial pressure against that, as the prestigious and powerful Bell Labs had performed most of the Navy's undersea surveillance work as a contractor for some years, and there was concern the program sponsors at the systems commands would by-pass their own Navy lab and continue to work with Bell. It was well-founded. A Chief of Naval Material-directed study four years later demonstrated the reality of that concern: A key conclusion of the "Report of the Task Group for the Point Loma Laboratories" (Goland Report, see "DoD/CNM laboratory studies" below) stated,

> If NUC is to fulfill its responsibilities as the lead Center for undersea surveillance, a substantial expansion of its activities in this area is required. Thus far, NUC has been unable to attract funding support for an expanded effort in the deployment of advanced experimental systems and for the development of the 'wet end' technology needed to field and maintain such systems. One reason for this state of affairs is the current Navy reliance on an industrial contractor for major system development and the consequent lack of support for an adequate technology program at NUC.

Despite that reliance, or perhaps due to it, with approval of the Navy assistant secretary for R&D, Harry Schenck was selected Center program manager for surveillance systems, organizing teams to test the Towed Array Sensor System, Large Aperture Marine Basic Data Array, and other systems.

PME-124

There were also encouraging changes at the systems command level. The Fiscal Year 1972 (July 1971 to June 1972) Center command history reported:

> In line with added mission responsibility as the principal Navy RDT&E Center for undersea surveillance, a NUC scientist was designated to serve as Assistant Technical Director to the

Undersea Surveillance Program Office (PME-124), at the request of the Naval Electronic Systems Command.

Based on the earlier management meeting, that scientist was Harry Schenck. A fall 1972 newspaper issue provided basic detail, that PME-124 was the Navy's Undersea Surveillance Project [sic] Office; it was responsible for air, sea surface, and fixed undersea surveillance; and Dr. Schenck was now the full-time assistant technical director for the project office.[40] Schenck, who would relocate to Crystal City where Naval Electronic Systems Command had its headquarters, would provide "scientific support in the areas of modeling, processing, propagation and environmental effects and also in system engineering and analysis."[41]

NUC support of PME-124 will be addressed later in this chapter.

Diving into the depths

Dr. William McLean's uncanny ability to spot leadership talent had set a low-level employee in a low-key organizational unit on the road to senior management, as described in the earlier discussions about Bill Powell. He had in mind a similar road for Howard Talkington. There were obvious differences, of course, including the one Powell mentioned in his repeated objections to his own selection: Talkington had earned an engineering degree from a major educational institution, the prestigious University of Southern California. Following up on that and fulfilling the promise with notable achievement, his leadership during the CURV recovery of the H-bomb from the Mediterranean Sea had earned him a Navy Superior Civilian Service Award. Additionally, through his practice of "volunteering" his services, discussed in Chapter 12, he had attracted Levering Smith's chief scientist Dr. John Craven and the Polaris ballistic missile test

---

[40] *Seascope*, October 27, 1972, 1. Based on other more credible citations, "Program" is the correct term.

[41] Somewhat coincident with his PME-124 assignment, Schenck was promoted to associate head of the Undersea Surveillance and Ocean Sciences Department. In September 1976, he was selected head of the Undersea Surveillance Department. He took the year 1983 off to pursue postdoctoral studies in signal processing and computer science, and then spent the 1984-85 academic year as a visiting professor at the Naval Academy. He taught courses in sonar and differential equations, while performing independent research on sonar theory. Later in his career he lectured in the People's Republic of China and at the Russian Acoustical Society in Moscow. He retired in 1995.

program to San Clemente Island. Nevertheless, his selection as department head pushed him more squarely into the spotlight.

Powell's selection and subsequent achievements had brought to the lab the new technology area of marine mammal operational systems. Talkington would accomplish something similar in an emerging field even more important to an "undersea" center: ocean engineering.

Within a year of his appointment, Talkington was finalizing the plans for an event to put the undersea center "on the map" in that new technology area. Heeding the joint Dr. McLean-Captain Bishop certainty about the need to "go undersea," he had put together a commendable attempt to demonstrate that, placing all the Center's undersea eggs in one basket at San Clemente Island for a major ocean engineering show to the world.[42] Vehicles, concepts, towers, and catamarans were all assembled at the fairly close off-shore island under Talkington's overall management, and the news media was invited in large numbers to witness all this hardware in action. As the Center newspaper reported:

> It's show time at San Clemente Island as Center scientists and engineers display their ocean engineering capabilities to VIPs from other Navy agencies and from the press. The two-week show will feature almost all of NUC's ships and submersibles, as well as a number of other projects currently underway… More than 20 different projects were displayed at the pier area in Wilson Cove.

Those included a CURV III static exhibit, a model of the oceanographic tower, the Semi-Submerged Ship, displays on the Marine Mammal Program in Hawaii, "and the latest developments in underwater optics systems and working hardware."[43]

The Cable-controlled Underwater Recovery Vehicle, five years after world-wide headlines following recovery of the lost hydrogen bomb from the Mediterranean Sea, appeared in its latest iteration that, less than two years in the future, would generate even more such headlines for rescue of submariners about to die. Manned vehicles and platforms from San Diego, Hawaii, Point Mugu, and Port Hueneme would demonstrate their utility, while unmanned systems much less complex than CURV would dive and surface for the TV cameras.

The Center's motion picture group was there with its cameras as well,

---

[42] The sheer scope and variety of the Center's undersea projects during the late 1960s and throughout the 1970s and beyond, led substantially by Talkington, defies convenient summarization. That is why it was presented in detail as the sole subject of Chapter 12.
[43] NURDC Seascope, September 17, 1971, 1.

shooting thousands of feet of 16mm film, and masterfully editing and scripting it into an official Navy production titled *Eyes of Inner Space*, which won several industry awards. Also related to the major publicity effort, the Technical Information Division, of which the motion picture group was a part, published NUC TP (Technical Publication) 278, *Ocean Engineering*, in January 1972. Its fifteen chapters reported on various aspects of the topic, including submersibles with panoramic visibility, remote control underwater vehicles, launch and retrieval of submersibles, diver equipment, salvage systems, and ocean platforms.

While another example of McLean's understanding of leadership skills and interest in novel thinking is perhaps unnecessary, consider the story of Frank Gordon, a Ph.D. mechanical engineer from the University of Kansas who arrived at the Naval Undersea Research and Development Center in the early 1970s. Like Howard Talkington, he possessed substantial academic credentials and, like Talkingon and Bill Powell, would advance to and serve as a department head in a most spectacular fashion. Once upon a time, however, Gordon was a fairly new employee when his own department head, Bud Kunz, told him the technical director wanted to meet with him and made it clear, "Whatever he asks you to do, you don't tell him 'no.'" Understandably somewhat apprehensive, Gordon drove from Pasadena to San Diego to meet with McLean, who with little fanfare asked him to take over a major submarine-related weapons program. Gordon responded he would do his best, but he'd been working at the lab less than two years, he knew little about submarines, and he had never been on one. "He said that's why he wanted me to manage it, adding that he already knew the answers he would get if he gave it to more experienced people and he wanted new ideas."[44]

Name, mission, and leadership changes

Spring and summer of 1972 brought significant changes at the undersea

[44] Tom LaPuzza, "Dr. Frank Gordon, Code 71 Department Head and SES member, retires after over 38 years of federal service," Space and Naval Warfare Systems Center Pacific *News Bulletin*, Vol. 1, No. 11, Aug. 2009, 3. The program, External Stores or External Stowage, sought to augment firepower of nuclear submarines, which Gordon characterized as submerged power plants with torpedo rooms added almost as an afterthought. They hardly compared to World War II diesel-electric boats, he said, with twenty, thirty, even forty weapons aboard. The concept was to increase the subs' firepower by placing weapons external to the pressure hull.

center, one in the name itself. A handful of weeks after Charles Bishop relieved Grady Lowe as Center commander three years earlier, the Navy had changed the recruiting-negative “Undersea Warfare” title to “Research and Development,” which in its abbreviation (NURDC) caused Captain Bishop enough discomfort he spent much of his tour trying to get it changed. On June 9, 1972, three weeks before the change-of-command at which he would retire, he finally got what he’d desired, as the Navy officially dropped the “Research and Development” in favor of the streamlined “Naval Undersea Center.” Bishop, with twenty-one days left in his active Navy career, had little time to enjoy his triumph before he became a civilian.

(Captain Bishop didn’t go far away in his retirement. In addition to owning a home on Point Loma about a mile from the front gate of NELC, he went to work at the Marine Physical Laboratory, located as it had been since the disestablishment of the University of California Division of War Research in Building 106 in the NUC waterfront area. That building was a stone’s throw from Quarters L, his official residence during his three years as NUC commander.)

With the new name came a mission “redefinition,” reflecting most notably the Center’s increasing interest and involvement in undersea surveillance: “to be the principal Navy Research, Development, Test and Evaluation Center for undersea surveillance, ocean technology and advanced undersea weapons systems.”[45] The Ocean Sciences Department became the Undersea Surveillance and Ocean Sciences Department.

Accompanying the change in title and mission was the leadership change, as Captain Charles B. Bishop, World War II submarine captain and the Center’s second commander, retired with thirty years of commissioned service. He was relieved of command, temporarily, by Commander William J. Gunn, the technical officer. Gunn would serve about ten weeks until the designated relief officer, Captain Robert H. Gautier, reported aboard after completing his assignment as Commander, Caribbean Amphibious Ready Group.

On June 29, the day before the Bishop-Gunn change-of-command, the Center celebrated both that event and its fifth anniversary with a banquet at a Mission Bay hotel. The usual hail-and-farewell speeches and gift presentations perhaps were overshadowed by a summary of impressive Center technical accomplishments delivered by Technical Director Dr. William B. McLean and the presentation of the first Lauritsen-Bennett Award for Excellence in Engineering. (Center-level

[45] Naval Undersea Center *Seascope*, June 23, 1972, 1.

award observances had been initiated the previous year with the presentation of the Curl Award for Excellence in Science to Dr. Edwin L. Hamilton, honoring Dr. Gilbert H. Curl, a highly regarded ocean scientist and department head at both NEL and NUWC. Stated plan was for the science and engineering awards to be presented on alternate years.) The L-B award honored individuals who had played essential roles in formation and early years of the organizations culminating in the Naval Undersea Center: Dr. Charles Christian Lauritsen of the California Institute of Technology, who had been instrumental in the establishment of the Naval Ordnance Test Station; and Captain Rawson Bennett II, the post-World War II Navy Electronics Laboratory commander. Their wives were guests at the banquet.

To a standing ovation, Charles G. "Chuck" Beatty was presented the first Lauritsen-Bennett Award, based on his years of outstanding leadership of torpedo development. A 1942 graduate of the Massachusetts Institute of Technology, Beatty had served during World War II as a captain in the U.S. Army Air Forces. Following the war, he attended the California Institute of Technology, earning his master's degree in electrical engineering. Beatty began working at the Pasadena Lab in 1952. While advancing to head the Torpedo Development Division, he led development of the Mark 46 torpedo. He had previously been recognized with the

Charles G. Beatty

The two major undersea center awards were the Lauritsen-Bennett for Engineering, the first presented to Charles Beatty in 1972, and the Gilbert H. Curl for Science, presented to Dr. Edwin Hamilton in 1971.

Dr. Gilbert H. Curl

Dr. Edwin Hamilton

Naval Ordnance Test Station's L.T.E. Thompson Award for contribution to "significant advancement in the Navy's antisubmarine capability."[46]

In addition to the serious award, there were also several humorous presentations, one by Captain Bishop to Hawaii Lab Director Jesse Burks, who received two pennant-shaped flags with "NUC" on them to continue his successful efforts to acquire additional property on the Marine Corps Air Station for lab use.

A special edition Center paper reported on festivities, for which McLean provided a written statement reflecting subjects covered in his banquet speech.[47]

Organizational challenge

In both the speech and newspaper article McLean noted the Center's "major problem" during its half-decade of existence was "bringing together two organizations that were raised and trained under different philosophies of laboratory operation." (That identical challenge would face his successor, Dr. Howard Blood, in less than five years, when NELC and NUC were combined to form the Naval Ocean Systems Center.) The primary sponsor of the Pasadena Lab, McLean noted, was the Bureau of Ordnance, "which encouraged its laboratories to think in terms of total systems." The Bureau of Ships, on the other hand, which supported programs originating in San Diego, sought technology base products from its labs and "maintained the technical cognizance of systems in Washington."

McLean reported "considerable progress" in merging those philosophies, and cited Chief of Naval Material Admiral I.C. Kidd's "objective of giving the laboratories more systems responsibility" as a positive step forward. Captain Bishop had objected to that philosophy even before he arrived at NUC, but he retired the day after McLean's banquet remarks.

McLean went on to cite progress in a number of areas important to the Center:

--establishment of two operational marine mammal systems

--installation of integrated sonar system aboard USS *Dolphin*, which steamed to the Sea of Alaska for systems effectiveness testing. "It showed the increased

---

[46] Naval Ordnance Test Station *Rocketeer*, November 13, 1964, 5.
[47] NUC *Seascope*, June 29, 1972, 2.

acoustic effectiveness that can be achieved with submarines that operate at greater depths."

--establishment of the Marine Life Sciences Lab

--development of *Sea-See*, a catamaran floating on unsinkable Styrofoam "logs" with an underwater viewing chamber.

Major emphasis was given, as might be expected with McLean's love of the sea and particularly the sub-surface portion of it, to development and operation of manned and unmanned undersea vehicles. From *Trieste*, which had been recertified for 20,000-foot operation, to the shallow-depth submersibles *Makakai* and *Deep View*, he expressed the value of these vehicles which "allow people to get down below the surface of the ocean, where they can observe undersea processes. That will be very useful in the area of identifying marine organisms that produced sonar signals similar to targets."

He believed they would be equally valuable in identifying sea floor areas suitable for placement of sonar arrays.

Technical projects

In addition to the relatively recent emphasis on undersea surveillance and ocean engineering, several long-time Center technical areas of responsibility were pursued with a variety of projects and programs. The sonar work, begun as one of the first concentrated efforts back in the early days of the Navy Radio and Sound Lab (see Chapter 3 particularly), played a large role in the early undersea center technical program, as engineering development began on the PAIR sonar (described below); the BQS-15 close contact sonar was developed for nuclear submarines; and USS *Glover* (AGDE-1) (see Chapter 10) was employed to evaluate the use of multiple sonar data for weapon control and to determine the range and bearing accuracy of the SQS-26 sonar. Art Roshon, whose pioneering efforts in the field had earned him the Navy's highest award, now managed the High-Resolution Sonar and Countermeasures Division, responsible for these sonar refinements. One of his branch heads, Rod McLennan, developed a facility for the AN/BQS-15 Submarine Sonar project. Positioned off the end of a Center pier in forty feet of water in San Diego Bay, it could lower sonar devices weighing up to two tons into the bay at various depths on a sixty-foot-long railway for underwater testing.[48]

Somewhat coincident was substantial work on the Performance And Integration Retrofit (PAIR) of the Center-developed AN/SQQ-23 sonar, a project originating at the Navy Electronics Laboratory before the 1967 transfer of employees. Managed by Harvey Klee, the effort was designed to provide an improved anti-submarine warfare capability over the existing fleet system, the SQS-23, used to detect, track, and provide fire control information on submarines. Intended for deployment on more than a hundred Navy ASW platforms, the system completed engineering development and successfully passed TECHEVAL and operational appraisal testing in 1970-71. Upon approval for service use, a contract was awarded for the first sixty-four production units.[49]

The development team received the Navy Award of Merit for Group Achievement.

Subsequently, a new, solid-state transmitter was designed and developed to replace one with high failure and maintenance rates on both the SQS-23 and SQQ-23.[50] The ongoing PAIR development work faced a major hurdle in that the test barge at Lake Pend Oreille, Idaho, was inadequate for its requirements. In late 1972 and early 1973, a contractor, using pontoons supplied by the Navy Construction Battalion Center at Port Hueneme, California, fabricated a 300-ton test barge with a large center well through which equipment could be lowered for testing, allowing the PAIR test and evaluation to be completed successfully.

U.S./U.K. Sonar System

Rod McLennan's assignment after the test facility on the pier was heading an international cooperative effort titled the U.S./U.K. Sonar System Program. The program involved constructing a sonar for installation on the British destroyer HMS *Matapan*. Initiated in 1969, the program sought to develop a surface system to investigate the bottom bounce mode of sonar propagation. NUC teamed on the program with the Admiralty Underwater Weapons Establishment, located in

---

48 "Sonar test facility operating soon," NURDC *Seascope*, January 16, 1970, 4.
49 NURDC Command History, 1 July 1969 through 30 June 1971, 5 & 7.
50 NUC Command History, 1 July 1973 through 30 June 1974, 4.

Portland, England, a Royal Navy research and development laboratory similar to NUC. The two organizations worked together on several projects of mutual interest over the years and participated in exchanges of scientists as well as scientific information.

Following hardware development, Center personnel from San Diego and Lake Pend Oreille embarked on plans to set up a test range at the lake. Those plans were subjected to a rude awakening when a heavy storm at the end of January 1972 sent "Big Charlie," the facility's principal test barge, to the bottom of the fifth deepest lake in the U.S. This essential platform took with it a substantial amount of hardware and calibration equipment required for the U.S./U.K. system testing.

NUC personnel led by Rod McLennan (inset) mounted a small set of panels from the U.S./U.K. sonar system for HMS *Matapan* to test at the Lake Pend Oreille facility.

Acknowledging the potential for a delay in the start of testing, McLennan moved forward with a plan to replace the lost asset using a secondary testing platform called the "50-ton barge."[51] Much of the required equipment was initially fabricated at the San Diego Naval Station and shipped to Idaho, where it was

[51] "Combined Fleet Engineering Effort Overcomes Barge Sinking Crisis," NUC *Seascope*, October 27, 1972, 2.

employed to modify the existing barge for use in testing. Critical efforts included welding onto the barge twelve pontoons for additional required flotation.

With the platform challenge solved and new calibration equipment purchased, the team established a test range on the lake, consisting of a vertical line array 1,500 feet down range and 225 feet underwater. The sonar array was suspended via crane over the side of the barge and lowered to a depth of two hundred feet: "We selected the 200-foot depth to test the equipment free of boundary conditions. We feel the performance evaluation will be simplified at that depth," McLennan reported.[52]

Following successful completion of testing, the sonar—one of the largest ever built, with forty-seven cabinets of sonar electronics and thirty-eight panels of transducer elements—was installed on the British ship. McLennan and his team were presented the Navy Award of Merit for Group Achievement for the effort.[53] (In the previous chapter, NELC's development of microelectronic technology was detailed. Those who tend to think of electronic components as tiny and fragile would be amazed to view the 63-foot-long, twenty-plus-ton sonar array developed for the U.S./U.K. program.)

Weapons development

Although the Mark 46 torpedo was accepted for fleet use in the late 1960s, work on refinements continued, as did development on its successors, including the Mod 1. The Center was assigned development of that model and allotted thirty-six months and $33 million to accomplish it. Program manager Mort Heinrich explained the Mod 0 had been manufactured commercially based on Center designs, but the industry model "had some terrible problems, from a propulsion

---

[52] "Sonar Testing Underway At Lake Pend Oreille Facility," *Seascope*, October 27, 1972, 1. The issue included a story on the effort to replace "Big Charlie," and another detailing projects at the lake. It introduced the six engineers and technicians of the crew—supervisor Ed Haines; engineer Gordon Bivins and electronics technician Les Teston, both of whom provided significant support to the barge modification; Leo Caron, Corwin "Corky" Mallot, and Bob Griffin. The half-dozen worked year-round at the lake, regardless of weather conditions; in the article Teston is quoted as saying during his seven-plus years on the crew, "… we've only missed two days of work on account of the weather. We went to work those days, too, but it was 35 below and the boats wouldn't start."

[53] NUC *Seascope*, January 24, 1975, 3.

standpoint. Number one, it was a solid propellant and the solid propellant… was a difficult turn-around. It wasn't something that was easy to clean the torpedo up. It was a dirty fuel…"[54]

The solution was switching to Otto fuel, developed initially by a German refugee named Otto Rightlinger in conjunction with New York University (although Heinrich stated the Navy had developed it "independently.") A new propulsion system was designed to operate on that liquid fuel, and development proceeded with Center personnel overseeing a contract for the effort. Heinrich pushed for Center autonomy in the process: "We will design and build this torpedo for $33 million, but we're in charge. Not people back in Washington having the contract, but we were going to be in charge. I could write a work order tomorrow."

With the agreement in place, substantially outside normal Navy contracting procedures, the new torpedo was completed within the three-year assigned period.

Simulation support of technology development

Earlier chapters related the work both by the University of California Division of War Research and the Navy Electronics Laboratory in fabricating state-of-the-art sonar transducers:

> If you go down to Building 132… there is a huge kiln (maybe 15 foot in diameter), where we used to fire our own piezoelectric ceramics for building transducers. We cast both Lead-Zirconium-Titanate (PZT) and Barium-Titanate (BT) metallic oxides. We made our own transducers and transducer arrays for various sonar systems.[55]

In the mid-1970s, the Center employed its sophisticated computer resources to "display the structural vibrations of Navy sonar transducers."[56] In a cooperative program with the University of Utah (from which, by the way, a number of the Center's New Professionals had been recruited), NUC personnel were able to "draw pictures" visually illustrating those vibrations. Such an illustration, which "appears to be a photograph but is actually a perspective drawing linking the geometric coordinates" of the elements of the transducer, allowed the designer of such a device to test its performance before it was even built. This simulation, very

---

[54] Mort Heinrich oral history conducted by Tom LaPuzza June 20, 2012, 20-21.
[55] Morris Akers oral history interview conducted by Tom LaPuzza, February 7, 2013, 3.
[56] "Computers Aid Transducer Study," NUC *Seascope*, March 8, 1974, 3.

similar to what was done with torpedoes, provided sophisticated and realistic performance evaluation at a fraction of the cost of actual testing.

In addition to the description immediately above, Chapter 10 reported in some detail on the development of the Mark 46 torpedo. For longevity in fleet deployment as a primary weapon, it had few equals.[57] The earlier description mentioned sea testing of the torpedo, and indeed a good deal of that was required and accomplished. It was, however, expensive and time-consuming, and a method of testing without firing a shot had been developed in the 1950s at the Pasadena Lab. Employing first analog computers, then a "hybrid" complex of both analog and digital machines (the first major such complex in the country), physicist Lloyd Maudlin had assembled a simulation facility at the Pasadena Laboratory that could test torpedoes realistically dozens of miles from the ocean.[58]

Lloyd Maudlin: making simulation successful

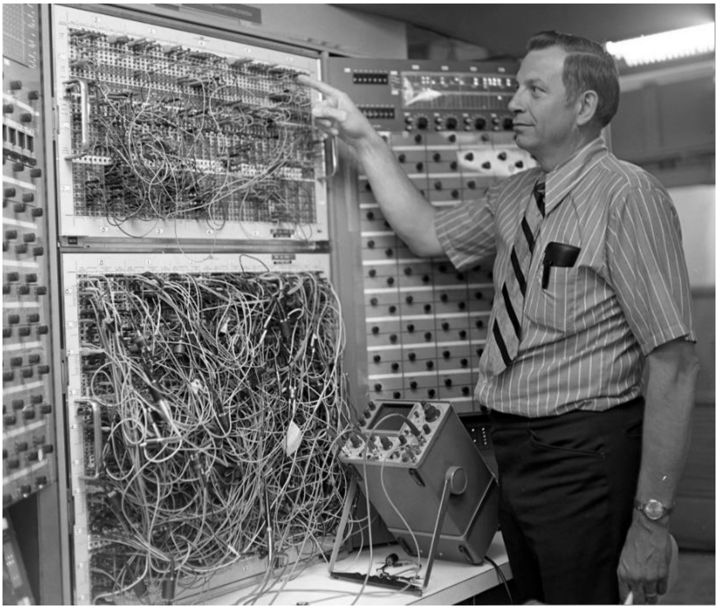
Lloyd Maudlin was an Army Air Force B-24 gunner and radio operator during World War II. Afterward, he earned a physics degree from UCLA in 1949, followed by a master's from the University of Southern California three years later. In the midst of his studies, he started work at NOTS Pasadena, where an analog computer-driven flight table was the fundamental simulation system. "My first job was to make it work," he said. He succeeded, and in 1952 he ran the Navy's first simulation program on the system to evaluate a Mark 37 torpedo.

That successful effort was only the beginning: "Since then I've worked on every U.S. torpedo developed, as well as some foreign ones." Selected as the first head of the Simulation Branch and eventually of the Simulation and Computer Sciences Division, Maudlin noted he was pleased to observe "the parallel growth

---

[57] Mort Heinrich was program manager for the torpedo for several decades. When he arrived at the Center for an oral history interview in June 2012, he was shown a copy of the current issue of U.S. Naval Institute *Proceedings*. The cover photo showed the test launch of a Mark 46 Mod 5 torpedo just a few months earlier. He was stunned.

[58] Naval Ocean Systems Center *Outlook*, December 19, 1980.



Lloyd Maudlin arrived in Pasadena while still in college and established the weapons simulation capability.

of our understanding of ocean acoustics phenomena and the development of computer technology." That allowed his organization to develop increasingly sophisticated (thus increasingly accurate) simulation capabilities. For his pioneering efforts in simulation, he received the Navy Meritorious Civilian Service Award in only his second year of service (and those were days when such awards were very rare). Maudlin supervised Pasadean computer and simulation resources for two decades, then oversaw the complex move of those resources to San Diego (see his "open letter" below). He served as the first department head for computers and simulation at the Naval Ocean Systems Center (NOSC), until he retired in 1980.

Actual hardware included in testing

In discussing his lengthy career in the field, Maudlin explained that simulation involves employing a computer to duplicate essential elements in a test, such as the hardware under test and the operating environment for that hardware: "We use the actual torpedo guidance and control systems, which are connected to the computer. The computer simulates the rest of the torpedo in great detail, the ocean and targets, real and false, such that the torpedo thinks it's actually in the water."[59]

In the 1970s, the facility ran twenty hours a day, six days a week. The simulation work, Maudlin said, was based on

> a philosophy of three basic points: First, we simulate the physics of what happens in the water. Second, we use as much of the actual hardware as possible so that we can discover any deficiencies. Third, we use the engineer as an actual part of the analysis. He can then question the information as he runs the program rather than waiting till all the data is gathered.[60]

The facility, and that philosophy, "has been used on every torpedo developed by the United States since 1951."

During simulated runs, the torpedo was suspended in an interconnected set of three "frames" that allowed it actually to maneuver with six degrees of freedom. Given sonar "hits" on a simulated target submarine, the torpedo could dive, ascend, and turn left or right in response to its on-board computer calculating a course to intersect the target. The engineer could determine prior to the test the target's course and speed, and watch the torpedo's reaction to changes in those, allowing nearly immediate correction of subtle errors in the computer's logic system. If desired, target evasive action could be input in the middle of the run.

The simulation facility was used to develop and test "new improved circuits for MK 46 and everything in the way of logic that went into the MK46 MOD 1 and the MK48." The Mark 48 was the Navy's heavyweight, submarine-launched torpedo under development at the Navy lab in Newport, Rhode Island.[61] Analysts at the NUC simulation complex provided Newport engineers data evaluating the performance of the Mark 48 Mod 0 and Mod 1 to consider in determining which model to develop.

Initially the facility was employed for evaluation only, but as torpedo designers increasingly understood the value of simulation, it was employed for development work as well. Certainly cost saving was an important factor. At the

---

[59] NOSC *Outlook,* December 19, 1980.

[60] "NUC Real-Time Simulation Facility Working On Torpedo Development," NUC *Seascope,* August 4, 1972, 3.

[61] NUC, on the other hand, developed lightweight torpedoes that could be launched not only from submarines but from surface ships, aircraft, and rockets as well. Basic size comparison: Mark 48—19 feet long, 3,500 pounds; Mark 46—8.5 feet, 500 pounds.

time of the 1972 *Seascope* article, Maudlin commented, "This has grown into a ten-million-dollar facility, and we estimate that we have provided the equivalent of over a billion dollars' worth of analysis to the Navy in the last five years." (In his retirement article in the December 19, 1980 NOSC *Outlook*, he was quoted as saying a single run on the simulator instead of at sea saved tens of thousands of dollars, and "the number of runs on the Mark 46 alone certainly exceeds 20,000.")

Also of consideration was the time factor. An engineer considering a new design for a component could make one in the shop, replace the current one with it, and try it out immediately. And then, if necessary, "back to the drawing board."

As discussed in Chapter 6, Operational Test and Evaluation Force (OPTEVFOR) is the Navy's objective testing authority on all new technology going into the fleet. After OPTEVFOR personnel conducted ten torpedo test runs, the NUC simulation facility, without seeing their results, also conducted the tests and duplicated those results. Force officials were so impressed they immediately arranged to set up several thousand runs at the facility, and soon afterward NUC simulation became an integral part of OPTEVFOR testing.

Propeller history

An interesting use of the simulator was also detailed by Gerald Mosteller, a physicist who worked in the Underwater Ordnance Department's Hydrodynamics Branch. He wrote a bylined article for the Center newspaper in which he recounted briefly the history of propeller development, a process he deemed initially "trial-and-error."[62] After explaining cavitation, essentially the formation of bubbles as a result of a propeller's spinning motion, he explained a torpedo propeller must avoid the certain result of cavitation—noise—as it "would reveal the presence of the torpedo to the enemy or would mask the signal the torpedo is attempting to pick up for its guidance."

Characterizing a torpedo as "a machine with a power plant as powerful as a small automobile engine and with only a few cubic feet of room for warhead, motor, fuel, and auxiliary equipment," he described the numerous calculations required for propeller efficiency and concluded it was only possible with the

[62] NUWC *Seascope*, June 6, 1969, 1.

UNIVAC 1108 computer in the simulation facility. With the computer providing the complex designs, the Center's machine shop, with its numerical control machines, could produce the unique propellers.

Other aspects of Pasadena's wide range of production facilities were the pattern shop and the foundry. Highly skilled woodworker Rod Hill could produce a pattern for an object, which was employed to imprint corresponding voids/impressions in closely packed sand, into which foundry supervisor Harold Lemon and his crew poured liquid metal to form the desired object. In this fashion, for one example, the team was able to make a set of four afterbodies for the Encapsulated Harpoon missile, each three feet high and weighing a hundred pounds.[63] Foundry personnel used 750 pounds of casting aluminum for each afterbody, but generated substantial cost savings since the castings required only a few days' machining to satisfy the exacting specifications, followed by x-ray inspection to determine any defects. None was found. As noted in the article, "The foundry provides three significant services to the Center: it produces prototype hardware with minimum documentation, produces hardware for urgent schedules, and provides documentation prior to start of regular production."

The Center's foundry production of Encapsulated Harpoon missile afterbodies was part of a larger Navy program to develop the Harpoon anti-ship missile as an air-to-surface weapon, with additional capability for launch from land, surface ships, and submarines. The Center, with expertise dating back decades in underwater weapons launch technology, was tasked with testing the contractor's product for submarine launch. In response, a series of tests was conducted at San Clemente Island on the missile's Encapsulated Inert Test Vehicle, the capsule which would be essential for such a launch. Several versions of the capsule, one designed by NUC, were employed in the testing using the Center's tripod launcher for underwater firings.[64] More than a hundred missiles were fired using that launcher at the Long Beach Naval Shipyard and at San Clemente Island. Additionally, dockside launches from USS *Sturgeon* (SSN-637)-class nuclear submarines were conducted in San Diego.

Another "tripod" developed by the Center was employed for photography under unusual and difficult circumstances during the first at-sea test launches of Encapsulated Harpoon. Three vacuum cups allowed affixing a tetrahedral-shaped

---

[63] "100-Pound Castings Made," NURDC *Seascope*, May 26, 1972, 3.

[64] "NUC Conducts Test Series On Encapsulated Harpoon," NUC *Seascope*, April 5, 1974, 3.

aluminum frame to the external hull of a submarine, in this case USS *Pintado* (SSN-672). An instrumentation camera was attached to the frame, positioned on the sub's hull near the opening of a torpedo tube. When the Harpoon capsule was ejected during testing at San Clemente Island, the camera captured the underwater launch in precise detail. The attachment cups held the frame and camera in place for many hours of diving and surfacing and even for steaming at speeds up to ten knots. The vacuum cups were developed for the External Stowage and Launch program, a short-lived effort at the Center in the early 1970s.[65]

Center personnel also contributed substantially to the fly-off competition between contractors for the Tomahawk sea-launched cruise missile, designing and fabricating the Hydraulic Torpedo Tube Launcher (HTTL). Actual testing was done in late 1975 to early 1976. High cost and limited availability of submarines, coupled with safety considerations, led to launcher development. When completed using a standard Mark 54 torpedo tube, the launcher essentially duplicated firing from a *Sturgeon*-class submarine. The 75-foot-long, seventeen-ton HTTL could launch a 4,000-pound test vehicle at velocities up to fifty feet per second.

Forty inert launches and three boosted flights were conducted off San Clemente Island, with the launcher suspended underwater from a floating crane at a depth of 190 feet. In addition to the launcher, the Center operated photo instrumentation cameras that recorded data essential to performance evaluation, resulting in contractor selection for missile production.

The NUC team developing and operating the launcher was accorded the Navy Award of Merit for Group Achievement.

Other projects

Like NELC, the Naval Undersea Center had several major product lines, but also a number of smaller areas of concentration that produced valuable technologies for the Navy. A sampling of those are included below.

---

[65] "Vacuum Cups Provide Easy Sub Attachment," NUC *Seascope*, February 8, 1974, 3. For information on External Stowage, see footnote 44 above on SSC Pacific *News Bulletin*, August 2009.

Acoustic barriers for submarines: In July 1974, Meyer Lepor, head of the Biosystems Research Department's Airborne Noise Branch, was cited with the Secretary of the Navy Cost Reduction Award for "value engineering equally effective but less costly acoustic barriers for the SSN-688 (*Los Angeles* Class) submarines."[66] Those newly designed barriers, in addition to providing substantial and critical quieting of the boats, saved the Navy more than $7 million and earned Lepor the Presidential Management Improvement Award the following year.[67]

Diver Navigation System: Given the nature of its business, the undersea center required a large number of divers to support the testing of new technologies. Rather than hire commercial divers for that specific purpose, the Center conducted training programs for its own scientists and engineers. (The Navy Electronics Laboratory, which had previously managed the same or similar programs, also had an active diver training program.) One project, through several iterations, specifically sought to increase the effectiveness, and safety, of those divers.

Initiated as the Diver Navigation System in the mid-1960s, it was "'designed to enable divers to [1] home in on and navigate relative to marking beacons, and [2] navigate relative to a fixed polar coordinate system in the work area,'" according to Ben Saltzer, who managed the project.[68] The Position And Location System (PALS) was "the first concrete example" of the system, fabricated at the Pasadena Lab for testing by aquanauts of SEALAB III. PALS featured an FM receiver with three hydrophones to provide a diver information on his location. Employing continuous-signal FM transmitters located in two or three known positions around a work site allowed a diver not only to find the way "home," but also to determine current position accurately.

The Divers Underwater Omni System (DUOS), a PALS upgrade,, "uses an acoustically-created polar coordinate grid system… which will enable the diver to determine his bearing and range within the grid."[69] Planned system refinements included replacement of an initial hand-held version with a diver helmet display.

Polymer studies, drag reduction: Dr. J.W. "Jack" Hoyt and William D. White

---

[66] NUC *Seascope*, July 26, 1974, 1.
[67] NUC *Seascope*, August 22, 1975, 1.
[68] "Aquanauts get navigation system to save time, boost capability," Naval Undersea Warfare Center *Seascope*, October 4, 1968, 1.
[69] Thomas J. LaPuzza, "Diver Navigation System enhances divers' safety and work capability," NURDC *Seascope*, January 23, 1970, 3. Based on Ben Saltzer paper "A Deep Submergence Divers' Navigation System."

collaborated on several papers related to their research with polymers, aimed principally at reducing drag on weapons, such as torpedoes, as they sped toward their targets. During Hoyt's research, he proposed, and gained a patent on, the use of such polymers for reducing turbulent flow during a blood transfusion. The researchers also suggested the use of polymers to assist individuals with high blood pressure. That condition, when caused by atherosclerosis, was characterized by fatty deposits in blood vessels, leading to turbulent blood flow around those blockages. The scientists demonstrated the condition could be alleviated by introducing polymers into the blood stream, resulting in laminar blood flow. Hoyt later demonstrated the value of using polymers in the water hoses of fire fighters.[70]

Sea snakes: NUC scientists using internal Independent Research/Independent Exploratory Development funding prepared a handbook specifically on "appearance, habits and distribution of some of the most common sea snakes, land snakes and crocodiles of southeast Asia" as a guide "to prepare field personnel to deal with them in the safest possible way."[71] Although the opening paragraph stated, "Our intent is to reduce fears based mostly on misinformation or ignorance," the authors acknowledged "sea snakes are highly venomous… their venom is from 10 to 20 times more potent than that of their cousins, the cobras and kraits." The handbook was printed with funding from the Navy Science Assistance Program, successor to the Vietnam Laboratory Assistance Program, and distributed to military personnel deploying to Vietnam to prepare them for dangers beyond enemy combatants.

Oceanography course for teachers: In an interesting project intended to spread knowledge, the undersea center presented a several-months' course for local science teachers, with educational credit from California State University at San Diego. Headed by Associate TD for Research Dr. Donald Wilson, the course essentially was set up and coordinated by Marjorie Moss of the Public Affairs Office, earning her a letter of appreciation from the Chief of Naval Operations. It featured nine of the Center's premier scientists and engineers and was kicked off with a dramatic presentation by Dr. George Pickwell, whose riveting opening was: "The sea is said to be cold and wet. It is also salty. More than that, it is a fascinating organic soup of interacting molecules…" Every speaker

made it clear that the amount of information known about the ocean is outweighed by the

[70] NUC *Seascope*, May 17, 1974.

[71] G.V. Pickwell, editor, *Handbook of Dangerous Animals for Field Personnel,* NUC TP 324, December 1972.

staggering amount that is not known… 'The burden is on you,' Pickwell told the teachers. 'You are the ones responsible for all those young people who want to go out and still, God bless them, still want to do something useful.'[72]

Megamouth shark: A good example of the "staggering amount unknown" was the surprise when Hawaii Lab project personnel pulled in a sea anchor deployed at a depth of about 500 feet for a test. Attached to it was a 14.5-foot, 1,650-pound shark never before seen by man, although they didn't know that.[73] Nevertheless, intrigued by its huge mouth, the crew hauled the shark aboard with great effort and took it back to the lab, where a technical officer who was a biologist got University of Hawaii scientists involved in examination of the fish. It was later identified as a new genus, species, and family of shark, given the name *Megachasma pelagios*, family Megachasmidae. Cited for assistance in the identification was Dr. C. Scott Johnson, a nuclear physicist whom Bill McLean invited to join the undersea center staff and who became a dolphin and shark expert in his later career (see Chapter 8).[74]

Trident submarine sonar: At the request of Naval Ship Systems Command, based on his expertise in sonar development, Harvey Klee lead a team which included fellow Center employees Dr. Gordon Martin and David Little to conduct the technical design review of the sonar bow array for Trident submarines.[75]

"Adapter Key Caps": A previous chapter discussed the concept of creativity, both in its perception and how it might be achieved, or at least encouraged. Unlike the positive characteristics cited, sometimes it is born of frustration and annoyance. Seemingly those were the inspirations of Lois Hogue.

In her days as a clerical employee in the Fleet Engineering Department, "copies" were generated by using carbon paper, interspersed with one or several sheets of thin paper, often in pastel colors, between the original and the typewriter platen. Hogue knew only too well the challenge of typing a lengthy document while answering the phone and responding to supervisory directions issuing from an inner office. Should the telephone-answering hand return to the keyboard one key to the left or right of proper position, the result was gibberish and a whole new set of pink, green, and blue sheets interleaved with more carbon paper.

---

[72] "Teacher-Students Hear From Experts," NUC *Seascope*, March 16, 1973.
[73] NUC *Seascope*, Dec. 17, 1976, 3.
[74] NOSC *Outlook*, September 10, 1983.
[75] NUC *Seascope*, September 28, 1973.

United States Patent [19]

Hogue

[11] **3,848,723**

[45] **Nov. 19, 1974**

[54] **ADAPTER KEY CAPS**

[76] Inventor: **Lois M. Hogue,** 3766 Dana Pl., San Diego, Calif. 92103

[22] Filed: **July 23, 1973**

[21] Appl. No.: **381,951**

[52] **U.S. Cl.** **197/102**
[51] **Int. Cl.** **B41j 5/16**
[58] **Field of Search** 197/98, 100, 102, 103

[56] **References Cited**

UNITED STATES PATENTS

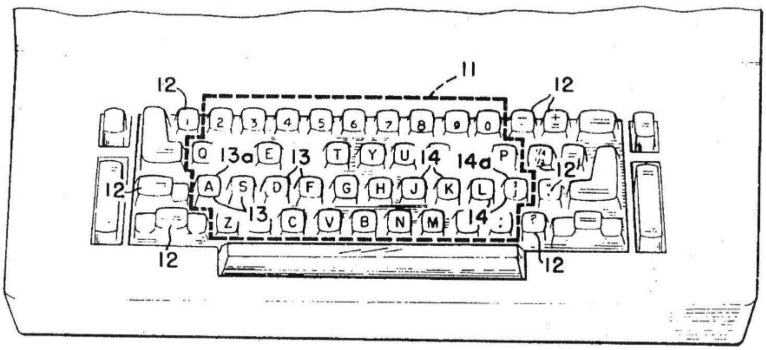
726,107	4/1903	Stanton	197/98
1,041,696	10/1912	Summerville	197/102
1,148,721	8/1915	Scott	197/102 UX
1,823,130	9/1931	Smith	197/102 X
2,484,886	10/1949	Henry	197/102
3,396,827	8/1968	Harwell	197/98
3,648,394	3/1972	Hepner	197/102 X

Primary Examiner—Robert E. Bagwill
Assistant Examiner—R. T. Rader
Attorney, Agent, or Firm—Richard S. Sciascia; Ervin F. Johnson; Thomas Glenn Keough

[57] **ABSTRACT**

An adapter key cap reduces the possibility of typographical errors on a modern typewriter having character and service keys arranged and aligned in parallel rows. A raised, beveled projection disposed on the key cap allows a typist to tactically know when the fingers are properly positioned on the "home keys". When a typist is frequently interrupted by other office tasks, a considerable savings in time is assured by the invention since there is no time wasted visually checking the positioning of the fingers after each interruption.

2 Claims, 4 Drawing Figures



Lois Hogue invented "Adapter Key Caps" for proper positioning of the hands on a typewriter keyboard without the necessity of looking away from the document being typed.

As a solution, she suggested something that was termed "Adapter Key Caps" in an invention disclosure in 1973. They were characterized by a ridge of some kind on certain "home keys" on a typewriter keyboard, such as the F and J keys, to orient a touch-typist's fingers without the requirement to look down to ensure proper placement. On November 19, 1974, Hogue received United States Patent No. 3,848,723 for her invention, which migrated effortlessly to the computer keyboards that would be appearing on secretarial (and management) desks everywhere in the near future.

Undersea surveillance

As noted earlier in the chapter, the Center was assigned a new leadership area in mid-1972, according to Naval Material Command Instruction 5450.27 of 27 June 1972:

> The Naval Undersea Center shall establish and maintain the primary (although not necessarily exclusive) in-house research and development capability for the following Navy and Marine Corps systems, subsystems and technologies: Undersea surveillance…

This formal delegation of responsibility for undersea surveillance, "essentially the long-range detection and monitoring of submarines,"[76] set into motion several actions: Dr. Harry Schenck was assigned as assistant technical director of the Undersea Surveillance Program Office at Naval Electronic Systems Command (PME-124), with a handful of NUC personnel for support. In line with his PME-124 responsibilities, Schenck and several associates began short- and long-term visits to the Naval Facility (NAVFAC) at Brawdy, Wales.[77] Their tasking was to initiate the first substantive testing of undersea surveillance system performance *by a Navy activity*. The emphasis added to that sentence was based upon prevailing protocol, that the contracted commercial source, Bell Labs, developed and installed the surveillance capability, and then did the testing on the performance of that capability. This arrangement had existed for some time, and clearly was to the advantage of the contractor.

When Harry Schenck and his team assumed their responsibilities to test system performance in the early 1970s, the several-decade-old Sound Surveillance System (SOSUS) provided the Navy's basic capability to perform undersea

[76] Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma*, 105.

[77] The facility was a former Royal Navy base that had been shut down by the Ministry of Defence and then reopened as a Royal Air Force Base. In Britain, it was the RAF rather than the Royal Navy that pursued underwater acoustics. "The NAVFAC was right down on the main road (as close to the shore as possible) while RAF Brawdy and its gates were set back a mile or so." Frank White oral history interview conducted by Tom LaPuzza August 14, 2018, 39.

surveillance. Arrays of hydrophones positioned on the seafloor in strategically important geographical locations—in shallow water near the coastlines and at "choke points" such as the Greenland-Iceland-United Kingdom (GIUK) Gap—allowed gathering of data on transiting submarines, which was sent to processing stations located ashore nearby. (Brawdy was near the GIUK Gap.)

Deep sound channel

A bit of orienting history might be helpful here: Lehigh University scientist Maurice Ewing in 1937 "made a seminal observation while doing seismic refraction experiments" in the North Atlantic.[78] Based on the results of his experiments, he suggested that acoustic energy, particularly at low frequencies, could travel great distances underwater with little attenuation.

> He further postulated that if there were horizontal sound propagation paths in the deep ocean that avoided surface and bottom reflections – a so-called 'deep sound channel' – acoustic signals could travel hundreds, or even thousands, of miles and still be detectable by judiciously located hydrophones.

Ewing and his associates performed later experiments confirming the existence of the deep sound channel, and during World War II he suggested the potential of this channel for naval communication at long distances underwater. From that scientific research came the post-war development of the air-sea rescue system Sound Fixing and Ranging (SOFAR), which was described in Chapter 5.

At an important meeting on ASW technology in early 1950, physicist Frederick Hunt, who had headed the Harvard Underwater Sound Laboratory prior to and during World War II, convinced attendees the SOFAR channel could be employed effectively to detect submerged submarines at extremely long distances.[79] Contracts subsequently established by the Office of Naval Research

---

[78] Edward C. Whitman, "SOSUS—The 'Secret Weapon' of Undersea Surveillance," *Undersea Warfare*, Winter 2005, Vol. 7, No. 2.

[79] As detailed in Chapter 1, Hunt was one of the pre-eminent scientists in underwater sound for decades. In May 2015, the Acoustical Society of America sponsored a session at its 169th meeting dedicated to the seminal early efforts in ASW. Presenters and their topics: William A. Kuperman of UCSD Scripps Marine Physical Laboratory: "The University of California Division of War Research and the Marine Physical Laboratory"; D. K. Knobles, Evan K. Westwood, and Thomas G. Muir: "Columbia University Division of War Research

demonstrated the feasibility of the approach, and that, bolstered by the recognition low frequency sound could penetrate the deep sound channel from almost any source depth, provided the technical basis for the Sound Surveillance System (SOSUS).[80]

Early experiments were conducted on arrays off Sandy Hook, New Jersey, followed by testing of the first full-sized prototype array—a 1,000-foot-long line array of forty hydrophone elements—deployed in about 1,500 feet of water off the island of Eleuthera in the Bahamas. Data gathered by individual hydrophones were transmitted to a facility ashore on multiconductor armored cables for processing.

Based on its success in detecting cooperating U.S. submarines, the first operational SOSUS arrays were positioned in the mid-1950s, basically in a sort of semi-circle along the East Coast from Barbados to Nova Scotia. According to Frank White, one of the original members of the NUC team posted to Wales:

> In the early 1950s Bell Labs and Western Electric were hired to start putting those arrays in… And the whole idea was, then, when it was first built, because there weren't nuclear submarines [at the time], they were designed to find the snorkeling diesel submarines. Because when they would snorkel, they'd run a snorkel mast up and then the diesels would light off and they would be down deep enough that sound would go into the deep sound channel axis and could be detected at very long ranges.[81]

From those strategic positions, the arrays were able to survey the Atlantic to the mid-ocean ridge, and particularly the abyss to the west of it. Subsequently, arrays were placed in several locations along the Pacific Coast, usually isolated from population centers, and then around Hawaii. The intent was to provide an underwater version of the Distant Early Warning (DEW) line, alerting operational forces to the approach of submarines to the U.S. coastlines. Typically, the arrays were positioned on the edge of the continental shelf, looking outward to the greater

---

and the work of Ewing, Worzel, and Pekeris"; Frederick M. Pestorius and David T. Blackstock: "Contributions to the development of underwater acoustics at the Harvard Underwater Sound Laboratory (HUSL)." The latter presentation concentrated substantially on Hunt, under whom Pestorius had studied. Pestorius, as a Navy captain, was commander of the Naval Ocean Systems Center on Point Loma from 1984 to 1986. The sole lacking presentation at that acoustical society meeting was on the substantial ASW contributions of the Point Loma Navy Radio and Sound Lab and the Navy Electronics Laboratory. Efforts were made later to correct the oversight, specifically by Dr. Pestorius.

[80] At the time, the acronym "SOSUS" was highly classified; as unclassified solutions, the research and development effort was titled "Project Jezebel," and the actual array installation was termed "Project Caesar."

[81] Frank White interview, 13.

sea depths where submarines normally operated. Cables on the seafloor carried acquired signals to nearby shore processing stations (termed Naval Facilities—NAVFACs), where hundreds of LOFARgram writers recorded them twenty-four hours a day by "burning" frequency-versus-time representations on long strips of "smoky paper."[82]

Frank White noted the value of the information provided did come with something of a downside: "A little smoke arises from your lofargram… and in your nose; when you go home, your face is black and when you blow your nose it's black, and your skin is black and your shirts are black."[83]

As the SOSUS effort became more structured, the Navy established a new enlisted rating—OT, ocean systems technician—and trained sailors in that rating to "read" LOFARgrams. Equally important, two major commands were established: Commander, Ocean Systems Pacific and Atlantic. Serving as both type commanders and operational commanders,

> the operational arm of the command was the Evaluation Center (EC), a 24/7 watch center… The NAVFACs sent their contact reports and when requested, raw acoustic data to the EC which then did all the evaluation, correlation, localization, fusion, etc., and all reporting to higher authority… The EC was the heart of SOSUS: Ford Island in the Pacific; Norfolk in the Atlantic.[84]

(The original "targets" of SOSUS, as stated, were snorkeling Soviet diesel electric submarines. Since the first nuclear submarines fielded by Russia were extremely noisy, SOSUS provided a valuable resource in locating and tracking them. As ambient ocean noise increased, however, and Soviet engineering efforts significantly quieted their submarines, an upgrade of SOSUS technology became imperative. As we shall discuss in detail in Volume II, the Point Loma laboratory, with its assigned responsibility for undersea surveillance, would contribute

---

[82] Whitman, "SOSUS…": "… AT&T adapted its sound spectrograph, which had recently been invented as a tool for analyzing speech sounds, into a similar device called LOFAR – for Low Frequency Analysis and Recording – designed to analyze low-frequency underwater signals in near-real time. Both LOFAR and the spectrograph generated a frequency-versus-time representation of an incoming sound 'bite' on which the time history of its spectral content was indicated by the blackening of specially-sensitized paper by an electrostatic stylus that swept repeatedly along the frequency axis. In this way, the presence of distinctive submarine sound signatures – comprising both broadband noise and discrete frequency components ('tonals') – could be discerned against the ocean background in the composite signal picked up by an array." Triangulation of arrays reporting a specific contact allowed reasonable estimation its position.

[83] Frank White interview, 37.

[84] Frank White email to Tom LaPuzza, September 19, 2019.

essentially to the upgrades, collectively termed SOSUS Phase I and Phase II Backfit Programs.)

Early efforts in Wales

One member of the Center team temporarily assigned to Wales, Frank White, had served as a naval officer on SOSUS duty at the Naval Facility on Midway Island. He had hoped to make the Navy a career, but circumstances dictated otherwise. When he left the service, he was hired by the Naval Undersea Center as the undersea surveillance effort got underway. As his first assignment, he was sent to Wales with Dr. Schenck's team. Although he was the junior member, he was the only one in the group with operational experience, making him a valuable asset. White commented on the "substantive testing" the group performed on SD-C2, a new contractor-developed cable for surveillance arrays:

> Bell Labs had… an entirely new cable system, much more sophisticated.… everything that was going into NAVFAC Brawdy was all new gear. And we were going back to Bell Labs [in New Jersey] all the time. We were doing testing on their gear, and we ran a lot of our preliminary tests there. And with a lot of those guys, I was able to work very closely with them, at the working level. At the senior level, the management at Bell Labs *greatly* resented having us, having this laboratory, involved in the test and evaluation.[85]

This represented, in fact, the first time a Navy organization had performed rigorous testing on contractor-provided undersea surveillance products.

Although the NUC efforts at Brawdy and other NAVFACs related to evaluation of the hardware rather than integrity of the data collection and interpretation, the important thing was always the information: Is there a potentially hostile submarine? Where is it? Based upon interest in and concern about those submarines, the Navy, with NUC participation, developed a methodology for the prosecution of such targets, according to Frank White: Asked if sonobuoys were used to localize targets discovered initially with the arrays, he replied,

> Correct, that was how it all worked. We (SOSUS) would find it; the VP [Maritime patrol aircraft squadron] would fly on it. And then we could put a surface ship on it, a submarine on it, or keep aircraft on it, or a sequence of all of those. The goal was to get to what they called 'a kill,' a two-

---

[85] Frank White interview, 33-34.

> thousand-nautical-mile radius where they could drop a torpedo and kill the boat. That was the whole thing we did. But it required a lot of active coordination of which I was just becoming aware *but* it all started with us being able to find and localize the target.[86]

Long Range Acoustic Propagation Project

Several years before the Center was assigned leadership in undersea surveillance, the Navy had established a daunting research effort to study the acoustic characteristics of the ocean. The general objective of the Long Range Acoustic Propagation Project (LRAPP) was to increase the capability to detect and track Soviet nuclear submarines. Over a period spanning a quarter of a century, beginning in 1967, LRAPP would employ nearly two hundred scientists from Navy laboratories, the academic community, and private industry to perform the research required to achieve this objective. Among the small number of military scientists involved was Kirk Evans, who as a Navy captain would command the Naval Ocean Systems Center (NOSC) from 1993 to 1996. NUC, and its successor NOSC, would provide extensive support to LRAPP.

Henry S. "Hank" Aurand, who was employed at the Naval Material Command but transferred to NUC in the early 1970s, was the first project manager of LRAPP. When he moved west, he was succeeded by Dr. Roy Gaul, an acoustician and deputy director at the Naval Oceanographic Research and Development Activity in Bay St. Louis, Mississippi. Dr. Gaul's principal operational contact on the project was a unique organization in the Office of the Chief of Naval Operations: to address Navy concern about the state of ASW,

> in 1964, a new organization, the Director of Antisubmarine Warfare Programs—designated OP-095—was formed… Its first commander was VADM Charles B. Martell. OP-095's mission was to focus on, and solve, the ASW problem… this move was more than extraordinary within the OPNAV organization—it was unique…. Before the formation of OP-095, no organization within OPNAV focused on the function of ASW as a complete system… The selection of VADM Martell… proved to be extraordinarily successful.[87]

Remarking in 2003 on current development following an ONR-sponsored LRAPP convocation the previous fall, Dr. Gaul wrote a white paper on the

---

[86] Frank White interview, 18.

[87] Louis P. Solomon, "Memoir of the Long Range Acoustic Propagation Program [sic]", U.*S. Navy Journal of Underwater Acoustics*, Volume 61, No. 2, April 2011.

potential for "expanded analysis with modern computational tools" of data gathered during "comprehensive measurement exercises" three decades earlier.[88] In that paper he also provided fundamental background on the early program effort, writing,

> The Long Range Acoustic Propagation Project (LRAPP) sponsored a series of major environmental acoustic field experiments in the late sixties and early seventies. The exercises encompassed a broad range of scientific and operational objectives. A common theme was determination of environmental influence on low frequency (10-500 Hz) signal propagation and ambient noise.

LAMBDA

While the early LRAPP exercises sought to gain comprehensive knowledge of the characteristics of the deep sound channel and underwater acoustics in general, Hank Aurand had moved to NUC and proposed the concept of a mobile version of SOSUS. Such a capability could be deployed in short order to replace a malfunctioning SOSUS array and also would allow positioning of information-collection sensors in locations where traditional SOSUS hardware wasn't feasible. In response, the Center patterned the Large Aperture Marine Basic Data Array (LAMBDA) after commercially available equipment.[89]

Morris Akers, who for decades participated in Center sonar and surveillance efforts ranging from firing ceramic transducers to managing an ocean surveillance division concentrating on systems concepts and analysis, remarked,

> Dr. Hank Aurand was one of our top scientists and he had an idea for this long towed array concept that could provide a fleet operational item. We then developed LAMBDA, and Tracy Ball was the program manager for that effort… The idea was, 'Let's pull this long towed array to find Soviet submarines,'

essentially using the technology employed to locate undersea oil fields.[90]

LAMBDA was developed at NUC with funding provided by the Defense Advanced Research Projects Agency. It was a large sensor array (literally miles

[88] Dr. Roy D. Gaul, "LRAPP Exercises Revisited," 26 June 2003.
[89] *Fifty Years of Research and Development*, 106.
[90] Morris Akers oral history interview conducted by Tom LaPuzza, February 7, 2013, 23. Tracy Ball later headed the Center's Undersea Surveillance Department.

long) that would be towed behind a surface ship with what Akers characterized as fairly low-key technology: "1960s' electronics with 1940s' array technology taken from the oil field exploration industry." Despite the characterization of "low-key," this was in fact a revolutionary, first-of-its-kind concept.

The principal problem was finding a suitable tow ship. Akers said one was located in a dry dock, contracted for use through the Military Sealift Command, refurbished, and the LAMBDA array and processing equipment were installed. Then it was off to sea on multiple lengthy tests to determine the effectiveness of the array, "sometimes for thirty-forty days. That was a little long."

The efforts on LAMBDA, which would lead to perhaps the Center's most important undersea surveillance contribution to the Navy—the Surveillance Towed Array Sensor System (see Chapter 15)—stimulated NUC's major participation in LRAPP, according to Akers, who was one of the Center's lead scientists for it.

While LAMBDA at-sea testing was underway, other surveillance efforts began. In the early to mid-1970s, NUC initiated a series of towed array projects, most importantly the AN/SQR-15 Towed Array Surveillance System (TASS), the first fully operational surface ship towed array sonar.[91] An article on presentation of the Navy Award of Merit for Group Achievement to the project team reported:

> The TASS team conducted intensive on-shore and at-sea testing of the prototype AN/SQR-15 (XN-1) Towed Array Surveillance System between September 1972 and January 1974, preparatory to introduction of the system to the Fleet… A number of team members spent many months at sea to meet the time schedule, and during the effort some 25 test plans and 35 formal technical reports were produced… The improved system has now been introduced into the Fleet, with detailed baseline performances and operating characteristics provided to Fleet personnel using the system.[92]

The story noted the same award had been presented to another TASS group for introducing the first fully operational surface ship TASS units into the fleet.

---

[91] Abbreviations and acronyms are valuable in saving space in documents and time in speaking; for the Navy, the "jargon" of acronyms is often amusing and sometimes confusing. Case in point: The first "S" in "TASS" is rendered in various newspaper articles of the time as "sonar," "surveillance," and "sensor." A December 1972 Center report is titled "Project Plan for Towed Array Surveillance System (TASS) Test Bed," a reasonable verification of the correct term.

[92] NUC *Seascope*, November 21, 1975, 1.

Saga ends

The "Pasadena Lab saga" detailed in Chapter 9 finally came to an end. Based on a Department of Defense shore infrastructure realignment, the aging pre-World War II collection of mostly wooden buildings on Foothill Boulevard was declared surplus, and the Center was directed to move its programs and personnel to San Diego. The April 27, 1973 edition of the NUC *Seascope* announced in type way too large to miss or ignore: "Pasadena Lab To Close."

Captain Robert H. Gautier, who had been Center commander since mid-September 1972, arrived in Pasadena to address a decidedly unhappy crowd of employees. Not only had they been reassured no move to San Diego was in the works (by Captain Gautier himself, and less than six months earlier!); they'd also been told a new major building was in the Military Construction bill. Captain Gautier expressed his concern, but confirmed there would be no last-minute reprieve. The lab, most of its jobs, and those who wished to continue in those jobs, were moving to San Diego by the following spring.

On that subject, the potential numbers of movers and stayers would require a large amount of personnel office and management number-crunching, followed by substantial guesswork. Clearly those who were of retirement age were unlikely to move south. Additionally, as in any adverse action (changing an employee's commute to work from five or ten miles to about a hundred was considered by the Civil Service Commission as a formally defined "adverse action"), employees who might be near retirement age with a certain number of years of service would be given the opportunity to retire with full, or nearly full, benefits.[93]

The younger employees—current or recent New Professionals and mid-career employees with a number of years' service who enjoyed their Center jobs—faced some tough choices. For one thing, the Pasadena housing market at the time was dismal if one was a seller, and the opposite was true in San Diego. Fortunately, Civil Service adverse action procedures allowed some government financial assistance in those cases. Additionally, there was a healthy job market in the commuting area, including, for those wishing to return to original sources, the California Institute of Technology's other technical progeny, the Jet Propulsion Laboratory, located less than ten miles away.

---

[93] "Voluntary Retirement In Major RIF's Authorized," NUC Seascope, June 22, 1973, 1.

Alternatively, most technical employees, based on the willingness expressed repeatedly to accept lower salaries for the opportunity to work on more exciting projects, enjoyed their employment on weapons and fleet support projects.

Still, it was not easy, leaving familiar surroundings, close friends, the kids' schools. Augie Troncale, cited earlier as one of those hired under the New Technician program, voiced probably a fairly common quandary:

> It was very hard because I was married; we had just had our first son and we had bought a home. We were established and very comfortable in a nice neighborhood. My wife had friends there. Her parents lived close by; my parents lived nearby. She definitely didn't want to move.[94]

Travel orders issued to "check out" San Diego

To improve the number of probable movers, employees were invited to San Diego on paid travel orders to check it out; members of the Employees' Services Organization were provided a tour of the five-story building under construction so they could pass the word about brand-new facilities awaiting those who relocated. (The building was slated for completion in late 1973, right in the middle of the fourteen-month Pasadena shutdown period, so a potential lab and office resource for those moving.) The Chamber of Commerce organized real estate agents to pair up with prospective homebuyers, the former well prepared to discuss attractive neighborhoods with nearby shopping and recreation venues and good schools.

Countering those efforts, but in a positive sense, immediately following the closure announcement, the attention of Pasadena (and San Diego) employees was directed to the fact all federal retirees would receive a 6.1 percent annuity increase on July 1, including anyone who retired by June 30. The June 22, 1973 *Seascope*, which announced retirement incentives to those facing reduction-in-force action, ran the names of forty-nine retiring employees. By the next issue (July 6), the number had jumped to seventy-seven, two-thirds of those from Pasadena.

In the meantime, the engineers and technicians and purchasing agents and clerical personnel continued to perform their daily functions efficiently, all the while with some sizeable percentage of their thought processes weighing the consideration: to move, or not to move.

[94] Augie Troncale oral history interview conducted by Tom LaPuzza, July 12, 2012, 10.

Ultimately each individual had to make his or her own decision as the calendar moved into 1974.[95] (Augie Troncale, incidentally, elected to move:

> After a few trips to San Diego, we decided that SD and the lab was the place for us… I realized that not many jobs offered these kinds of opportunities and experience with the subsequent chance to learn and grow… I was being exposed to so many different areas—design work, manufacturing, testing. I loved the opportunity I was getting to design a part, go to our model shop and personally machine the prototype, and then to test it out and generate the final report for review.)

He was one of many who moved; many did not. The number of retirees was so large the newspaper was unable to cover appropriately all those who had served lengthy and meaningful careers with the Center. Mass retirement ceremonies were held and newspapers the week before or the week following published long lists of names with years of service and little else.

And finally, it was all over. On May 3, 1974, the Navy officially disestablished the Pasadena Laboratory of the Naval Undersea Center. The property on East Foothill Boulevard—a commercial industrial facility turned into a government weapons factory that supported manufacturing of the atomic bomb and the design and development of several generations of anti-submarine warfare torpedoes—was turned over to the General Services Administration for disposal. It ultimately became a commercial self-storage facility.

Meanwhile, exactly two weeks later in San Diego, where hundreds of Pasadena employees had elected to continue their government careers, NUC Commander Captain Bob Gautier and Technical Director Dr. Bill McLean (a month from *his* retirement) cut the strings on a large piece of paper that fluttered to the ground, revealing a "Naval Undersea Center" sign of individual ocean-water-blue letters affixed to the front of a new five-story concrete structure. Numerous military and civilian speakers foretold exceptional technical achievements to benefit the Navy emanating from the Center's Administration/Laboratory Building. (At the time, Building 1 had been occupied for six months. The November 23, 1973 *Seascope* featured a photo with an impressive collection of boxes, file cabinets, and wastebaskets gathered in the back atrium of the building, with the caption "*MOVING DAY AT LAST.*")

---

[95] As it did so, *Seascope* issues covered retirement ceremonies: February 8—twenty-nine employees (held in Pasadena); March 22—twenty-four personnel (Pasadena); June 14 and June 28—forty-one civilians and two military were honored at a retirement luncheon in San Diego. Among the latter group was Technical Director Dr. William B. McLean.

Simulation facility moved to San Diego

Announcement of the closure of the Pasadena Lab had initiated a well-orchestrated move of the simulation facility to the new headquarters building nearing completion in San Diego. Lloyd Maudlin wrote an "Open Letter To Computer Users" for the September 28, 1973 *Seascope*, in which he provided specific details and exact dates on when each of the facility's computers would be moved, concluding, "It should be noted that this schedule will result in no interruption to the digital terminal users." The major computer complex designed into the new headquarters building in San Diego included a large working area for the simulation effort, which was up and running as people began moving into offices in Building 1. The new facility included the UNIVAC 1108 digital computer and an array of analog machines from Pasadena, plus an impressive new 1110 dual processor with a capability of six million computations per second and a 1230 digital computer.[96] Although intended for primary support of the simulation effort, the 1110 had substantial capacity to support other users:

> What I do remember is that for a time after the UNIVAC 1110 was installed in Bldg 1, primarily to simulate the ocean environment for torpedo development, some business computing (payroll, etc.), was done on it by NELC with a lot of tape drives being used to store and update the data and financial reports.[97]

Staffing doubled, from thirty Center employees in Pasadena to sixty in San Diego, with most of the added personnel assigned to the 1110 machine.

In addition to simulation, the facility was employed in evaluation of the Mark 116 Underwater Fire Control System. (Mark 116 Mod 0 through Mod 4, developed 1970-1975, were termed Underwater Fire Control Systems. Thereafter, the terminology changed to Anti-Submarine Warfare Control System [ASWCS].) NUC was the designated design agent, technical direction agent, data management agent, software support activity, and ISEA (In-Service Engineering Agent) for Mark 116 variants Mod 0 through Mod 7. These variants were fielded on numerous classes of destroyers and cruisers. The Center was also heavily involved in development of the Mark 111 system and the Mark 114 submarine system.

A key integrating component of the AN/SQQ-89 Surface Ship Combat

---

[96] "NUC Simulation Facility Aids Development of U.S. Navy Torpedoes," NUC *Seascope*, May 17, 1974, 3.

[97] Jim Gilbreath email to Tom LaPuzza, July 11, 2019.

System, the Mark 116 UFCS/ASWCS is a computer-based information management system employing standard AN/UYK-7 or AN/UYK-43B machines and providing enhanced ASW, surface classification, and localization capabilities for surface combatants.

Major efforts were expended on the Mod 1 in the early 1970s, resulting in a 1,200-hour reliability test and a three-week maintainability test in Fiscal Year 1974. The third unit of the Mod 1 was installed in USS *Virginia* (DLGN-38, mistakenly identified in the resulting award citation as USS *California*), allowing the ship to control torpedoes fired from deck tubes and launched via Anti-Submarine Rocket (ASROC).[98] An issue of the Center newspaper of the period reported the team developing the capability was presented the Navy Award of Merit for Group Achievement: "Although faced with a seemingly impossible time frame for completion, the team did in fact finish [on] schedule, within the original funding limits and with all technical goals met." Project manager Ron Thuleen commented this differed significantly from similar projects "in that NUC was given responsibility for the entire program."[99]

The Center through its various names and reorganizations worked on ASW control system development and testing for decades. With the Base Closure and Realignment Commission (BRAC) action of 1991, the work was transferred to the Naval Surface Warfare Center Dahlgren Division.

Undersea Weapons Lab

For many of those moving from Pasadena, specifically the engineers and technicians working the weapons projects, there was shortly an extra added benefit: the Undersea Weapons Laboratory was completed and dedicated at the end of June 1975. The relatively short time period from announcement to physical move to San Diego had required the weapons development function be "hastily set up in trailers, vans and the unused portion of a carpenter shop…"[100] While the weapons development engineers and technicians continued their focused efforts to meet sponsor requirements and deadlines at the same time they were moving their

---

[98] Naval Undersea Center Command History, 1 July 1973 through 30 June 1974, 5.
[99] NUC *Seascope*, November 21, 1975, 1.
[100] "Undersea Weapons Lab Dedication," NUC *Seascope*, July 11, 1975, 3.

offices, families, and household goods, facilities personnel matched their efforts in designing and gaining funding to build them a permanent home, specifically, "the first facility built by NUC to support ASW torpedo programs." Indicative of the sentiments of decades, Mark 46 torpedo program manager Mort Heinrich said at the dedication ceremony the substandard facilities "had not prevented the group from delivering torpedoes in the past, but the new building would make continued efforts easier."

The new lab provided 12,000 square feet of research, assembly, and test areas, and was designed to support three major efforts: the Mark 46 torpedo, the Mark 57 Mobile Submarine Simulator (MOSS), and prep areas for other ASW projects. The torpedo effort primarily supported Mark 46 Mod 5, the "Near-Term Improvement," usually rendered as NEARTIP. Intended "to counteract the ever-increasing submarine threat… This very important engineering development is directed toward a design suitable for retrofit into a sizeable portion of Torpedo Mark 46 Fleet inventory by 1977."[101]

The article also noted on-going work developing the torpedo component of the CAPTOR system effort led by an East Coast Navy lab.

MOSS was the latest in a series of mostly unconnected efforts, both at NUC and previously at the Navy Electronics Laboratory, to support the submarine force by providing a decoy for boats under vigorous attack. Rather than standing to fight, which probably would have been foolhardy if it was outnumbered and outflanked by multiple surface ships, the submarine would launch a MOSS device from one of its torpedo tubes and then shut down everything and come to rest quietly on or near the bottom. The simulator, making convincing submarine-like noise, would head off at high speed in some direction, with, the submariners hoped, the surface ships in hot pursuit. When the reverberation from exploding depth charges faded into the distance, the sub could get underway and head in some other direction. According to the following year's command history, "Debugging and proofing of the engineering development models of the MOSS MK 57 Mod 0 were completed, and technical evaluation has commenced."[102]

[101] "Lab dedication."
[102] Naval Undersea Center Command History, 1 July 1973 through 30 June 1974, 5.

Legendary leader retires

Events of the period (Pasadena Lab closure, early-out retirement incentives) resulted in the retirement of nearly two hundred NUC employees in the 1973-74 timeframe. Most significant of those was no doubt the retirement of Bill McLean. As China Lake people had felt a monumental loss when he decided to transfer to the new undersea center instead of remaining in the desert, so substantial numbers of the people he had labored to unite to some degree in San Diego found themselves at sea without that inspiring and stabilizing leader in the front office. (On the other hand, that was mainly an emotional feeling, since the steady hand of McLean's long-time deputy Doug Wilcox kept the enterprise steadily on course.)

As reported in the *Seascope* issue following the event, June 29, 1974 was a festive evening of outdoor celebration, poolside at a Mission Bay hotel, with a Hawaiian theme and music provided by Center personnel to honor Bill McLean. Guests left formality behind and donned island shirts and dresses; leis were abundant. A staid naval officer showed up in a baseball uniform with a long blonde wig. The analyst who had established the deterrence philosophy for the Polaris submarine-launched missile while at China Lake demonstrated exceptional talent at an electronic organ keyboard in San Diego.[103] Highlight entertainment was a singing quartet featuring Dr. Howard Wilcox, who between years at China Lake and San Diego managed a stint at General Motors; McLean's long time project associate Dr. Walter LaBerge, now Assistant Secretary of the Air Force (R&D); Dr. David Potter, Assistant Secretary of the Navy (R&D); and Vice Admiral William Moran, RDT&E director in the Office of the Chief of Naval Operations. Their memorably humorous lyrics disguised any lack of musical talent.

Before the party, Dr. Potter had presented McLean his second Distinguished Civilian Service Award, calling him "the greatest scientist of our decade in civil service." Admiral I.C. Kidd, the Chief of Naval Material, had offered personal congratulations at a meeting several weeks earlier. Among the large number of congratulatory messages were highly commendatory ones from California Governor Ronald Reagan and Chief of Naval Operations Admiral Elmo R. Zumwalt, Jr., whose retirement event coincided.

The Center newspaper prior to the party featured a two-page spread with

---

[103] Dr. Glover S. "Dub" Colladay.

words and photos of McLean receiving the President's Award for Distinguished Federal Civilian Service from Eisenhower in 1958, the American Ordnance Association Blandy Gold Medal in 1960, and the Rockefeller Public Service Award and congratulations from Vice President Hubert Humphrey in 1965. It showed a U.S. congressman shaking his hand in 1972 at his receipt of the IEEE Harry Diamond Award, and McLean chatting with JFK during his 1967 visit to China Lake. Of substantial note to McLean were his elections to the National Academy of Science in 1965 and the National Academy of Engineering in 1973.

There was a reasonable amount of speculation about reasons for McLean's retirement. Many decades of living with diabetes had barely slowed him down; he had weathered a heart attack and two eye surgeries and come back strong. He was, however, suffering more than he let on his last several working years from cancer of the tongue that had spread to his lymph nodes.

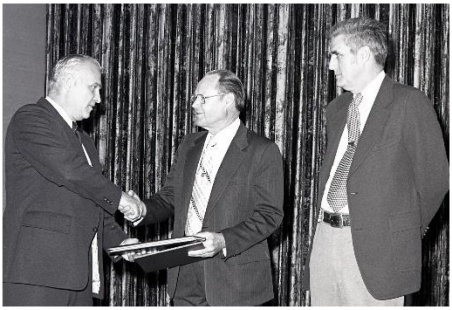
Perhaps health issues finally got the better of him. Maybe, negatively, he foresaw the coming of several of those tendencies of the Navy that he had characterized in his "Nine Ways to Ruin a Laboratory," i.e., increasing levels of review and scrutiny, centralizing of functions, the quest for organizational stability.[104] Or perhaps, positively, he considered the substantial accomplishments of that year—dedication of the Center headquarters building after three years of construction, final shutdown of the Pasadena facility, consolidation of Center personnel in San Diego—signaled a good time to call it a success and step down.

After he retired, he underwent surgery to combat the cancer, followed by a relatively new radiation procedure in Washington, D.C. in the spring of 1976. Weakened by the strain, he developed pneumonia and passed away August 25, 1976. Barely a month later, his widow, LaV, stood in front of Building 1, whose ground he had "broken" with a bulldozer, and unveiled a plaque rededicating it as the William B. McLean Laboratory.[105] "The Navy lab in the desert" at China Lake would also dedicate a major laboratory in his memory. The Navy would honor him in a manner that certainly would have pleased him: the United States Naval Ship (USNS) *William McLean* (T-AKE-12), a dry cargo and ammunition ship, was launched in April 2011.

---

[104] From his September 1959 presentation at the Thirteenth National Conference on the Administration of Research, titled "Management and the Creative Scientist." See: Cliff Lawson, *The History of the Navy at China Lake, California, Volume 4: The Station Comes of Age,* 681.
[105] NUC *Seascope*, October 8, 1976, 1.

As noted, the Assistant Secretary of the Navy had presented McLean the Navy Distinguished Civilian Service Award upon his retirement. For the critical six months after that retirement, while a nationwide search was underway to locate and hire a comparable replacement, Doug Wilcox had served as acting technical director. For that, and for his nearly decade of service as McLean's assistant and associate TD, he was presented the Navy Superior Civilian Service Award, as a surprise at an employee retirement luncheon.[106]




Major leadership changes at NUC saw (left, center) Dr. William B. McLean retiring, presented his second Navy Distinguished Award by Navy Assistant Secretary Dr. David Potter; looking on is Dr. Walt LaBerge, Assistant Secretary of the Air Force and member of McLean's Sidewinder missile team. At right, NUC Commander Captain R.H. Gautier and D.J. Wilcox (right) brief new TD Dr. Howard L. Blood.

New TD

While Wilcox was guiding the Center effectively during a period of continued growth, that nationwide search for McLean's replacement had settled on the director of the Applied Physics Laboratory (APL) at the University of Washington, Dr. Howard Blood. His selection was announced in September, and he was sworn in at the start of the new year.

Howard Blood had earned his Ph.D. in physics and mathematics from the University of Washington, and, remaining in place, he began working at APL shortly thereafter. He advanced over the next two decades to researcher, senior physicist, member of the advanced studies group, and assistant to the director. He ascended in 1971 to the director's position, in which he was responsible for programs dealing with ASW readiness, surface ship weapons accuracy,

[106] NUC *Seascope*, July 11, 1975.

underwater acoustic tracking, and development of new tracking techniques and mobile ranges. They were all essentially Navy programs.[107]

Although he had worked with Navy scientists before, the university laboratory he supervised was exceedingly small by comparison, with nothing approaching the variety of programs executed by the Naval Undersea Center. And it goes without saying his immediate challenge seemed almost insurmountable: somehow, with no actual Navy lab experience, to follow up a nearly three-decade career of the legendary Dr. William B. McLean. He certainly had big shoes to fill.

Blood spent half a year or so learning the organization; during that time, his military counterpart, Captain Robert H. Gautier, retired, relieved by Captain R. Bruce Gilchrist. In August 1975 there was a joint announcement of a Center reorganization, although, coming a couple of weeks after the change-of-command, Captain Gilchrist clearly had had little to do with it. The ordered actions included disestablishment of one entire department (interestingly, in light of the organization's future direction, it was the Sensor and Information Technology Department) and reduction of another to a staff organization, plus some cosmetic/name changes. These were made "to increase the Center's concentration on ocean sciences, long-range and near-term surveillance, in order to meet Fleet requirements and stay abreast of technological developments."[108]

While he was dealing with planning and then effecting that substantial organizational challenge, Dr. Blood also had to respond positively to the concerns of the Navy brass. Two such concerns were highlighted in mid-1976, as he was grappling with increasing pressure (detailed below) toward total consolidation of the two Navy laboratories on Point Loma.

The first came from the Secretary of the Navy, J. William Middendorf II, who spoke to a luncheon audience at a San Diego hotel on April 1. After proclaiming U.S. Navy superiority in numbers of aircraft carriers and quieter submarines, plus extolling the combat superiority of Navy and Marine forces and personnel based on experience in Vietnam, he cautioned against putting too much confidence in those facts. U.S. subs might be quieter (and NUC could have taken a bow at that point in the secretary's presentation), but the Soviets had more than twice as many of them (2.5 times as many, to be exact; 325 to 125). The Harpoon missile would

[107] As noted in Chapter 10, APL was one of the four university labs with which the Navy maintained a substantial working relationship in specific areas of expertise.
[108] NUC *Seascope*, August 8, 1975.

be deployed the following year (once again thanks substantially to NUC), he said, but the Soviets had had over-the-horizon missiles for "many years."[109]

The secretary's concern about the impossibility of an "instant Navy" was not exactly a problem for NUC and its technical director, since they weren't in the shipbuilding business, but it was obvious that pressure was imminent for the significant items which *were* their responsibilities, such as undersea surveillance systems to keep track of those 325 Soviet submarines and ASW torpedoes to counter them if necessary.

The second concern was more immediate for the Center, and came from Assistant Secretary of the Navy (ASN R&D) H. Tyler Marcy. NUC hosted a July 1976 meeting of Navy and Marine Corps activities to discuss Marcy's plan to form technical strategy teams to address Navy requirements based on the service's Strategic and Tactical Objectives. He emphasized the approach was not to be "a compilation of tasks," but rather "the major areas of thrust, the major prioritization, and the major areas of allocation of resource as you see it."[110]

Marcy had earlier tasked his Director of Navy Technology to select leaders of strategy teams: Howard Blood was to lead the ASW surveillance team and Howard Talkington was to head the ocean technology team. Team leaders selected their own members to work what the ASN had identified as the most significant issues: "elements that are threat-related… growing deficiencies in our current capability… emergent adversary capability… technical advances which have a large leverage on the rate of change of our capability."[111]

Another reorganization looms on the horizon

As mentioned several times previously, when a U.S. Congressional subcommittee visited Pasadena in the summer of 1967, shortly after the Navy had ordered reorganization of its West Coast laboratories, Bill McLean had hinted it was reasonable to consolidate his organization in San Diego. As early as 1960 he had met with officials of the Navy Electronics Laboratory to discuss joint work.

---

[109] "SecNav Warns Against Relying On 'Slight Edge,'" NUC *Seascope*, April 9, 1976, 1.
[110] "New Development Approach Implemented," NUC *Seascope*, August 13, 1976, 1.
[111] "New… Approach," 3.

Time marched on in its usual fashion, and although several hundred NEL employees had been transferred to the NUWC San Diego personnel rolls as a result of the 1967 reorganization, there was still a dividing line between the two organizations. The two centers' newspapers reported occasionally on the latest initiative to work together: *Seascope* in its May 3, 1974 issue reported "NUC, NELC Study Closer Cooperation." The article noted the two Center commanders had established working groups to examine potential areas of cooperation; safety, travel, and library functions were mentioned: "Specific further exploration of a joint automated library data system with on-line retrieval and of revised library cross-servicing arrangements was approved." Also listed as functions under consideration were supply, intelligence, and computer services. Bottom line was to increase cooperation in select areas, but not to consolidate them.

The obvious reason was stated: "Centralized functions could enable limited additional savings… However, there would be a significant trade-off in terms of service responsiveness and convenience." In other words, consolidating a function at NELC, for example, would save some funds but would substantially inconvenience NUC users of that function by increasing time and distance to travel up the hill for that service.

The Navy's need for cost savings, however, overpowered convenience. In the fall of 1974, Director of Navy Laboratories Dr. James Probus ordered NUC and NELC to combine their computer management and operations.[112] Recognizing Lloyd Maudlin and his team had consolidated computing resources previously ninety miles apart less than a year earlier as the Pasadena Lab was being shut down, this consolidation, physically at least, was fairly easy.

On the other hand, it was for some a difficult pill to swallow. NELC computer personnel had spent more than three years merely *planning* to purchase their IBM 360/65, and now they were being told, less than five years later, to unload that capability. Probus remarked, "The available evidence and the prevailing consensus argue for the transfer of the work load from the IBM 360-65 and for the future augmentation of the UNIVAC 1110 capability."

As a result, the two computer organizations began the task of coming together to provide a common service for their laboratories. It wasn't enough.

---

[112] "Probus orders consolidation of computer management," NELC *Calendar,* November 22, 1974, 1.

Base realignments, laboratory workforce reductions

As "big Navy" continued to scrutinize its expenses in early 1976, base realignments became a certainty. A study of seventy-four such realignments, reductions, and closures promised to "save the Navy $56 million annually and release 2,100 military support personnel for fleet assignments."[113]

ASN Marcy had earlier announced the Navy would reduce its laboratory workforce by almost ten percent, more than 3,600 technical personnel. (In one of those shifts that occurred periodically, dependent on who occupied politically appointed positions at higher levels of the Department of Defense, the drawdown in numbers of Navy in-house lab personnel "is intended to shift the balance of R&D efforts somewhat from within the Navy to industry." That certainly was more acceptable than such shifts in which the adverb was "substantially.")

While a purist might argue a Navy lab focusing on electronics was an unlikely partner for one that developed weapons, clearly consolidation of support functions was, if not preferable, then at least possible. One positive initiative was consolidating the supply and procurement functions, the rules for which were Navy-wide and not subject to varied interpretations by different systems commands or program sponsors. In all probability, NUC and NELC considered their request to higher authority for permission to merge these functions a milestone of cooperation and cost saving. In something akin to self-justification, the article stated,

> The two centers already have studied consolidation of selected common support functions, and the Navy has approved a merger of supply and procurement. Planning toward that will continue, but implementation will await a final determination in the larger NELC-NUC study.

As will be reported in Chapter 15, various studies were conducted. For all practical purposes, they meant very little in the big scheme of things, that being the Navy's vast infrastructure of R&D facilities. Where else could one consolidate two of the Navy's primary laboratories without a single dollar for personnel relocation costs, not a dime for adverse-action payments related to over-fifty-mile commuting distance change, and few if any changes that might ruffle the feathers

113 "NUC, NELC Consolidation Study Announced," NUC *Seascope*, March 26, 1976. Calendar ran an identical story, with a slightly different headline.

of resource sponsors or concerned congressional representatives? Additionally, there was a "history," as several hundred former NELC employees already worked at NUC, which now "owned" the property that previously was NELC's.

Almost before the ink was dry on that headline about the consolidation study, it was a *fait accompli.* The Naval Electronics Laboratory Center and the Naval Undersea Center would merge.

Dr. Frank Abbott

"Maybe I'll be a full-time babysitter," Frank Abbott said when he retired in 1976.[114] At the time, he had worked at the Point Loma Navy laboratories for thirty-four years, but Civil Service regulations of the day included mandatory retirement of federal employees at age seventy. Regardless of the regulation, Frank Abbott wasn't ready for full-time babysitting: "I'm only half done. It would take another 35 years to finish my work."

Abbott had begun his career at the two-year-old U.S. Navy Radio and Sound Laboratory in 1942. He arrived with an undergraduate degree from Stanford, a Ph.D. in physics from the University of Washington, and memories of two winters working in Chicago, memories substantially unpleasant for the San Diego native. His retirement story noted, during his early years on Point Loma, "he concentrated on radar propagation charts, submarine noise vibration suppression, towed hydrophone arrays and very long distance submarine radio communications."

Citing the dearth of submarine communication capabilities, his interest grew in more powerful low frequency radio transmitters as a potential remedy for that. One of his resulting responsibilities was tasking to design the radio communication station at Wheeler Mountain in Washington state, currently designated as the Jim Creek Naval Radio Station): "The Wheeler Mountain facility is the largest man-made object ever made, that I know of anyway. It's one-half mile high, one mile

[114] Mary Delmas, "Dr. Abbott Retires At Age 70," NUC *Seascope*, January 16, 1976.

Dr. Frank Abbott

wide and two miles long." The very low frequency (VLF) transmitter site broadcasts one-way communications to submerged Pacific Fleet submarines. VLF propagation was the focus of his attention after that effort. Among other projects, he studied marine mammal sound production in the five to fifty hertz range.

Dr. Abbott was transferred from NEL to the undersea center in 1967. Throughout his years at both labs, he supervised groups working in radio development and propagation, electrodynamics, and transducers.

An article in the Center newspaper a few years before he retired, in the days of the "energy crisis" when gas was scarce, suggested the possibility of riding a bike to work occasionally. Abbott had been doing so, daily, for more than three decades at the time, having worn out four bicycles in the process.

Abbott's principal hobby, shared with his wife, was "raising kids. We have three of our own and we adopted four others. Whenever one of the kids found someone who needed a place to stay, they would drag them to our place." As far as that full-time babysitting career, Abbott (and the Center) dodged that mandatory retirement regulation by returning as a consultant under the NUC Emeriti Re-employed Annuitant Program. His first post-retirement assignment was a trip two months later to the Center's calibration station at Lake Pend Oreille, Idaho.

Unfortunately, he couldn't take the bike.

15

Coming Together: The Establishment of NOSC

The very first pages of this history indicated we would discuss two World War II-era Navy laboratories on the West Coast, with anti-submarine warfare a principal concern of both. The rationale for that is realized in this chapter, when those two laboratories are consolidated to form a "single unit," which would ultimately become the present-day Naval Information Warfare Center Pacific. The quotation marks should suggest the obvious: the mandating of consolidation by higher authority seldom if ever results in an immediate turn from two organizations pursuing their own courses of action to a unified entity moving ahead in a single direction with a common purpose. The story of the two Navy West Coast laboratories certainly wasn't an exception.

There were significant reasons for consolidating the Naval Electronics Laboratory Center and the Naval Undersea Center. As early as 1960, NOTS/NUWC/NUC Technical Director Dr. William McLean had made a case for the value of establishing a consolidated ASW lab, and, as noted in Chapter 9, San Diego's Point Loma peninsula had been seen as a reasonable venue for such a lab. Over time, the two organizations had come to reside on that peninsula in close proximity and had studied, and effected, some minor consolidation of support functions. Certainly, there were technical capabilities and unique facilities at each lab the other could employ to its advantage.

In the mid-sixties there had been "big-Navy" moves—confused and complicated and eventually stymied by the Congress—to consolidate the anti-submarine warfare components of the electronics laboratory and the weapons lab at Los Alamitos Naval Air Station. There had been some general discussion about doing so in San Diego as well, but in the end the status quo prevailed.

In terms of personnel and cost savings in a consolidation, immediately one commanding officer and one lead civilian could be reassigned or dismissed, along with their secretaries and probably a few close advisors. There would be need for only one executive officer, one civilian and one military personnel officer instead of two, a process that lent itself easily to safety officers, public works officers, security, public affairs, mail rooms, and conceivably half a dozen other such positions. The Navy's plan to return uniformed personnel to sea had some attraction, but generally the military were small fractions of total personnel numbers at a laboratory. Visions of slashing the civilian payroll are dashed when they come up against Civil Service rules, although appropriate action such as a reduction-in-force certainly would save some salary dollars.

There were also distinct disadvantages to such a merger, as the individuals at the top particularly would discover. In the previous chapter, Bill McLean was quoted as saying the most difficult task in unifying the former NOTS people with the former NEL employees into the Naval Undersea Warfare Center was their "bureaucracy," in the sense that the two organizations had worked for different Navy bureaus, each of which had its own set of guiding principles, management philosophies, budgeting and funding procedures, and on and on. In short, their very way of doing business was substantially different. A program manager, a branch head, even an engineer or a technician working in the lab had been trained to function in a particular fashion, essentially as dictated by higher authority. Asking one or several or a hundred of those individuals to perform their normal work functions under radically different rules in a short space of time was a fairly formidable task. (And as we shall discuss in Volume II, the challenge of assignment organizationally to one systems command while working for and being funded by another was an almost impossible one.)

In the years after the 1967 reorganization establishing the undersea center and transferring several hundred personnel to it from the electronics organization, both centers had reorganized several times and developed what they believed the most effective, efficient management style for their programs and people. It is a typical, understandable, and reasonable human belief that "my way is the best." The "reasonable" is true in this case because the people involved invested large amounts of time and energy and funding in a determined effort to make it "best."

In the mid-1970s, however, consolidation was not seen by Point Loma lab personnel as imminent. Their newspapers reported in May 1974 on a "study of closer cooperation." In November the Director of Navy Laboratories ordered their computer resources consolidated. The undersea center's major "consolidation" story that year was Pasadena Lab closure and transfer of programs and billets to San Diego, which was a fairly dramatic (and painful to some) cost-saving measure.

DoD/CNM laboratory studies

Chapter 9 discussed in some detail the many studies ordered and reports written during the several decades after World War II. One (of many actually) significant to this history was ordered in the spring of 1974 by Dr. M.R. Currie, Director of Defense Research and Engineering. He was reacting to the concern of his boss, the Secretary of Defense, "about the quality and size of DoD Laboratories," since a quarter of the department's RDT&E was executed by and through the military service labs. In response, Dr. Currie directed his deputy, Dr. John L. Allen, to conduct a study with four principal issues: 1) Did DoD need laboratories? 2) If so, how should they be organized and managed for maximum efficiency? 3) Given insufficient capacity and differing political interests, how should RDT&E tasking be divided among DoD labs, private industry, universities, and others? 4) With those considerations studied and understood, what was a reasonable size for the in-house laboratory structure?

The results were published in the spring of 1975. Pertinent points from the report include:

> The Navy laboratory operation is largely a 'free enterprise system' in which the laboratories sell their services on an industrially funded basis to potential customers… the laboratories are encouraged to compete with one another with little regulation. The result is a system which exhibits an aggressive vitality in soliciting work. However, several years of such competition has led to a diffusion of capabilities and a plethora of altemate sources for almost any technology.[1]

Despite those seemingly negative statements, the study panel found the Navy's laboratory structure to be "reasonably matched to requirements" with reasonable costs.

Substantially coincident with the report publication, Chief of Naval Material Admiral F.H. Michaelis established a set of task groups to evaluate the laboratories under his authority. More than a dozen groups conducted such studies and reported out to the CNM. One such group visited and reported on the Naval Underwater Systems Center (NUSC).[2] Among the conclusions and recommendations were

[1] Director, Defense Research and Engineering, "DoD Utilization Study," April 28, 1975, 7.

[2] Naval Material Command, "Task Group Laboratory Utilization Study for the Naval Underwater Systems Center," 16 September 1975, titled informally the Sebestyen Report for the study leader, Dr. George Sebestyen, who had served as assistant director for tactical systems plans and analysis in the Office of the Secretary of Defense.

several related to the California labs, e.g., moving periscope development and all surveillance projects west, and shipping all torpedo development and related fire control technology to the East Coast.

Several months later, in the fall of 1975, CNM tasked another group to study the three Navy laboratories on Point Loma—NELC, NUC, and the Naval Personnel Research and Development Center, the latter occupying several buildings in NELC's Barracks Area. Headed by Dr. Martin Goland, vice-chair of the Naval Research Advisory Committee (NRAC), the task group comprised five individuals from systems commands and Navy research organizations.[3] Shortly after their arrival to begin the study, the task group members realized they had a substantial piece of work facing them, and precious little time to complete it. (They arrived in San Diego in late September after a preliminary meeting in Washington, and their report was due December 31.) Based on that, Dr. Goland split his associates into three sub-groups of two (adding a sixth member from the Office of Naval Research) to study each lab individually. The formal findings were emphatic in pointing out that although each sub-group had worked independently at its assigned lab, every member had reviewed and approved the entire report before publication.

What the group produced in a fairly short amount of time was an exceptional document reporting in depth on the labs, with general information—mission, numbers of civilian and military personnel, funding dollars—augmented by findings on adequacy of facilities, suggestions on technical project work for continued pursuit or transfer to another lab or private industry, and key issues.[4] The evaluators interviewed program sponsors to determine their satisfaction: In overall effectiveness, NELC was rated as "good to excellent," NUC as "excellent."

There was no mention of laboratory consolidation in the report, but possible "consolidation of functions" was noted "in addition to" the eight specifically assigned areas of study. A casual, even a fairly careful, reading of the report does

---

[3] Goland served as NRAC vice-chairman from 1974 to 1977 and during his last year chaired the committee. His "regular" job was as director and later president of Southwest Research Institute in San Antonio. Dr. Jerry Stachiw, whose work with Center submersibles was detailed in a previous chapter, worked with the institute on a number of occasions related to those underwater craft. After NUC completed its work with them, two of the craft were transferred to the institute for several years before being returned to San Diego to serve as "museum pieces" in the rear atrium area of the McLean Laboratory.

[4] Naval Material Command, "Report of the Task Group for the Point Loma Laboratories," January 1976, informally cited as the "Goland Report" in the typical naming convention.

not hint at the action taken by the Naval Material Command chief within a few short weeks of its publication.

Key points in the NELC section included the finding inadequate personnel and funding resources were being applied to multisensor, multiplatform systems. The task group was unanimous that "integrated systems of this kind have enormous potential for improving combat capabilities and reducing Fleet vulnerability."[5] It was recommended the Chief of Naval Development and the Director of Navy Laboratories "take positive action" to remedy this. The recommendation was one of a number in the committee's report that specified action to be taken by higher authority or cited failure by that authority to handle its responsibilities.

Another had to do with NELC's principal mission (and leadership role) of command, control, and communications, stating that "proliferation of C3 activities" through many organizations, mostly uncoordinated, prevented the Center from performing that mission:

> It is the Task Force's conclusion that C3 activities are presently diffused and dispersed among the CNM-commanded Centers to the point where a 'critical mass' of effort does not exist in one location. Since NELC is assigned the lead laboratory mission in this area, it is our view that its program should be strengthened so as to provide a technological focus for the Navy-wide effort.[6]

Of particular note was the finding only fifteen percent of the staff was engaged in command and control, a percentage deemed "inadequate."

Microelectronics lead recommended

Also cited as an area of "proliferation" was microelectronics. Acknowledging "the Navy requires an in-house capability for the design, engineering and small-lot fabrication of microelectronics devices, primarily of the LSI [Large-Scale Integration] type," the group favored centering that work at NELC.[7] While recognizing the Naval Research Laboratory required capabilities in this area for basic research and exploratory development, they recommended the San Diego center take the lead and assist other Navy labs in cooperative fashion. Believed

[5] Goland Report, NELC section, 20. (Each center's section is paginated separately.)
[6] Goland Report, NELC section, 23.
[7] Goland Report, NELC section, 14 and 19.

critical was the "small-lot fabrication," those which industry chose not to support based on the non-profitability factor of those efforts.

The task group noted NELC's human factors personnel spent too much time marketing to and working for other agencies, when their principal focus should have been in-house command and control projects. Blamed for this was the industrial funding concept (see remarks below about NIF versus block funding).

The group concurred with the Sebestyen Report recommendation that development of periscopes and submarine-related electromagnetic systems be transferred from the Naval Underwater Systems Center (NUSC) in Newport, Rhode Island, to NELC.

Two findings were laudatory in nature. The task group found NELC's program for weapon system software development (including cooperative efforts with Fleet Combat Direction Systems Support Activity) was "somewhat unique among Navy laboratories and is commendable."[8] A recommendation was made later in the report: "A special effort should be made to disseminate NELC experience to other Navy and DoD organizations."

The other concerned NELC's role on the Naval Aviation Logistics Command Management Information System. Cited as "an interesting case study" in that it was equivalent to a major Washington-based project, it thus was not reasonably a Navy laboratory assignment. That said, the task group noted the Center's management was "very successful" and recommended continuance of that role.

Undersea center

The NUC leadership assignment in undersea surveillance detailed in Chapter 14 received substantial attention from the task group, included in three separate sections. The group expressed concern about Navy reliance on commercial sources, and specifically a single contractor, in developing operational hardware:

> In essence, the heavy emphasis placed on contractor services, through Navy channels which do not interact with NUC, is making it difficult for the Center to implement a balanced program of its own… It is recommended that a high-level review of Navy policy in this area be undertaken. If an adequate in-house Navy capability is to be achieved, the role of NUC will have to be

[8] Goland Report, NELC section, 11.

> enlarged and given greater support. It is our understanding that the Center has repeatedly requested the funding and resources needed to expand its surveillance program, but these have not been forthcoming. It is for this reason that the Task Force feels that a review of this matter at the CNM level is important.[9]

The group cited the Sebestyen Report frequently, positively and negatively. They agreed with the recommended transfer of two specifically named undersea surveillance programs (SASS and SEAGUARD, otherwise unidentified), from NUSC to NUC, as well as the proposal to move surface ship ASW fire control systems, sonar, and tactical arrays to NUSC. Their disagreement was with the recommendation to center all torpedo programs in Newport, citing NUC's long history of successful lightweight torpedo development. Mentioned specifically was their agreement with assignment of lead role on the Advanced Light Weight Torpedo Program (ALWT, which would eventually become the Mark 50) to the Navy lab in San Diego. (Interestingly, in the distant future, as will be related in Volume II, the Point Loma lab would develop ALWT/Mark 50 all the way to fleet acceptance, then with Base Closure and Realignment Commission actions under BRAC '91, it would be forced to transfer it to Newport.) They reported "general consensus of those interviewed at the SYSCOM [systems command] and command level in Washington" with maintaining lightweight torpedoes at NUC and submarine-launched heavyweights at NUSC.

The Goland Report also cited NUC's New Professional program as "well-planned," with the "excellent feature" of several rotational assignments. Their praise specified the opportunity that provided management to evaluate prospective employees. What was missed (or at least wasn't stated) was its substantial value in recruiting those employees in the first place.

The marine mammal work was judged "impressive," but focus on operational system effectiveness had led to "continuing research suffering as a result." The task group emphasized the need for fundamental research, suggesting fleet personnel work development projects to free up NUC personnel for research. The negating challenges to such a use of military members: limited time between duty rotations, lack of knowledge of animal behavioral training and potential capabilities, general non-interest on the part of fleet sailors.

---

[9] Goland Report, NUC section, 10.

Industrial versus block funding

In one of the Goland Report major findings, mentioned a number of times, both NELC and NUC were cited as working too many small projects.[10] Concerns focused on the amount of time spent searching for sponsors, lack of long-term value for such projects, and insufficient management control.

These findings were entirely consistent with those of the report by Deputy Director of Defense Research and Engineering Dr. Eugene Fubini, detailed in Chapter 9 and reported nearly a decade and a half earlier. In his assessment, Fubini placed the blame generally on the "Navy laboratory system." Goland singled out the Navy Industrial Fund, which his team's report claimed resulted in organizations "populated by a large number of small-task 'entrepreneurs,'" not only at the two Navy labs in San Diego but "at all of the CNM-commanded Centers." The solution, according to the report, was "block funding."

Some months before the Goland committee arrived at Point Loma, the NELC newspaper reported block funding had been a major topic of discussion at a meeting the previous month at the Naval Weapons Center, China Lake:

> Block funding, said a summary of the decisions, will require careful planning to define goals, boundaries and funding levels for individual blocks of science and technology, and to identify main goals and themes for organization tasks in support of these goals. Each laboratory's technical director will be responsible for funds and programs.[11]

The report section on NELC allocated most of two pages (of thirty-four total) to this issue, while the NUC section had that many paragraphs (with the proviso it had been discussed in the other section). The task group noted "that block programming is not an automatic cure for the present difficulties. For a program to be effective, it must be planned jointly by Center and SYSCOM [systems command] management."[12] It was emphasized both parties had much to learn for effective funding, citing a 1974 case related to formulation of a block program for Navy and Marine Corps command, control, and communications: "Several

---

[10] Goland Report, NELC section, 26; NUC section, 20. In their separate reports, task group members counted 197 NELC projects and 339 at NUC funded under $50K; 86 and 63, respectively, in the middle category of $50-100K; and 163 and 117 funded at more than $100K.

[11] NELC *Calendar*, February 14, 1975, 1.

[12] Goland Report, NELC section, 25.

iterations were required, consisting of program suggestions by NELC and counter-proposals by the Command [Naval Electronic Systems Command], before a mutually acceptable plan was achieved… [It] was a long, iterative process."

Bottom line in both sections was block programming should be pursued vigorously, without any direction as how that should be accomplished. (And in fairness, that wasn't the task group's responsibility.)

In confirmation of the notion the Goland study was "not a consolidation" event, the task group noted two years of effort by NELC and NUC to consider potential cooperative or centralized functions

> to improve their effectiveness and reduce manning requirements and costs… In its own investigations, the Task Group did not identify any significant areas where further service consolidations would result in marked economics or manpower reductions.[13]

Thus, "no further action need be recommended at this time."

"No further action," but…

The Goland Report is dated January 1976, without a specific date, so precise timing is unknown. Nevertheless, the ink was hardly dry on report copies before Admiral Michaelis, on January 22, 1976, directed the two Point Loma Navy laboratories to develop a plan to consolidate. Dates provided were October 1976 for support functions and the following September 30 for the technical functions. One can only imagine the forming of committees, the gathering of data, and the cancelling of leave plans occasioned by those kinds of deadlines.

Whatever occurred must have worked, because on Tax Day 1976, the two commanders, Captain Robert R. Gavazzi of NELC and Captain R. Bruce Gilchrist of NUC, responded with a "Report on the Proposed Consolidation of the Naval Undersea Center and the Naval Electronics Laboratory Center." The forty-page document spelled out the planning committees formed, their conclusions a complete consolidation was preferable to a mere merger of support functions, and proposals on a name and mission for the consolidated organization.

The steering committee was the two captains and their technical directors, Dr.

---

[13] Goland Report, "Introductory Remarks," 3.

Clarence Bergman of NELC and NUC's Dr. Howard Blood. The technical committee, chaired by NUC's Doug Wilcox, included his associates Dr. Dan Andrews and Barney Towle, and co-chair Dr. C.D. Pierson and associates Dick Shearer, Walt Mitchel, and Myles Sheehy of NELC. Mitchel chaired the support committee, which included Wilcox, co-chair George Coulter and Commander Bob Nevin of NUC, and NELC's Commander Dee Rainville and Bob Sarvis.

The report's forwarding letter termed complete consolidation "both feasible and desirable," and recommended an implementation date of 1 October 1976.[14]

The report obviously sought a substantial leadership role for the consolidated Navy lab, citing as it did the Navy's primary responsibility, stated in the Policy and Planning Guidance of the Chief of Naval Operations for Fiscal Years 1978-1982:

> Sea Control is the fundamental function of the U.S. Navy, and is a prerequisite in one degree and form or another for all naval operations. The term Sea Control is used to mean control of the air, surface and subsurface areas in the time frame and degree necessary for accomplishment of a function or specific mission.[15]

In lockstep, the proposed title was Naval Sea Control Center. An earlier "Status Report" of the Technical Working Committee had provided four name options: Navy Sea Control Center, Navy Sea Control Systems Center, Navy Sea Control R&D Center, Navy Ocean Surveillance Center. The report also provided a proposed mission for the "Naval Sea Control Center": "to be the principal Navy RDT&E center for sea control systems, ocean surveillance, command, control, and communications." As noted earlier, the use of "Navy" tied the organization to the Navy exclusively. "Naval" widened the scope to include the Marine Corps.

The steering committee reported considering the CNM request for consolidation of most support functions October 1, 1976, followed by merger of technical functions and remaining support services September 30, 1977, and proposed complete consolidation by the earlier date. Somewhat confusing was the presentation of a Plan 1, which included only consolidation of support functions (seemingly inconsistent with CNM direction), and Plans 2A and 2B, the former the CNM direction and the latter complete merger by October 1, 1976.

The report confirmed several times that the consolidation plan had taken into

[14] NELC/NUC letter of 15 April 1976 to Chief of Naval Material, Subj.: "Plan for Consolidation of Naval Electronics Laboratory Center and Naval Undersea Center; submission of".

[15] "Plan for Consolidation," III-1.

account the recommendations of the Goland Report detailed above, and in fact dedicated a short chapter to that. Also reported were the identified personnel savings resulting from the consolidation: two military and thirty-four civilian billets at an annual cost savings of $1.33 million.

The NOSC fifty-year history cited four reasons for and benefits of the consolidation, including the obvious and laudable goal of saving money:

--Produce broad-spectrum systems capability

--Facilitate integration of intelligence, ocean surveillance, C3, and undersea weapons in support of the Navy's Sea Control mission

--Combine research and technology programs to provide increased flexibility and larger blocks of funds for broader and in-depth investigation

--Provide savings realized by combining support functions and through joint facilities usage.[16]

"Sea Control"

Although "Naval Sea Control Center" was *recommended* as the organizational title, the mission was stated (slightly differently in another part of the same plan) "to be the principal Navy RDT&E Center for command control, communications, ocean surveillance, undersea weapon systems, and supporting technologies."[17] That was followed with acknowledgement the mission "is wider than that of other CNM laboratories," and several rationales, including the fact reduction of Navy labs from fifteen in 1967 to nine in 1975 suggested the need for broader missions. The "full spectrum" authority (RDT&E, plus fleet support) proposed was intended to "emphasize the integration of the multiplatform, multiforce, multicommand level aspects of Sea Control." Failure in this was one of the Goland report's key concerns about NELC. As noted earlier, NEL's Dr. Ralph Christensen had favored a basic science focus and NUC's Captain Bishop complained his technical director Bill McLean wanted the entire gamut of responsibility. Rather than viewing this as a victory for one of those, this full-spectrum approach recognized the increasing complexity of technology demanded for effective naval operations required control of the entire development process.

Acknowledging agreement with higher authority is almost always a winning

[16] NOSC, *Fifty Years of Research and Development on Point Loma,* 96.
[17] "Plan for Consolidation," IV-1.

proposition in Navy/military circles, and the NELC/NUC proposal did just that by citing "paraphrased extracts" from the testimony of the Assistant Secretary of the Navy for Research and Development to the House Armed Services Committee. One fairly significant point is that while the Sebestyen recommendation was to consolidate all torpedo development at NUSC and Goland's response was to split lightweight and heavyweight weapons between the two labs, the consolidation report suggests, "Important advantages and economies can be realized by focusing future torpedo R&D, for both heavy and lightweight torpedoes, in the new Center."[18] Equally significant points are made about system integration and software reuse, the latter concept seemingly a number of years ahead of its time.

Facilities availability and requirements were addressed in a single page and part of a second, emphasizing Military Construction projects previously submitted would still be needed after the consolidation. "Particularly critical" were the NELC Electro-Optics Lab and the NUC Undersea Surveillance Lab.

The "Organizational Outline" and one of the key recommendations contained what was in fact a request, that the commanding officer and technical director incumbents be named by July 1, 1976, to initiate the implementation process, thus allowing consolidated organization stand-up by October 1. In response, NELC Commander Captain Robert Gavazzi and NUC Technical Director Dr. Howard Blood were named to lead the new organization.

Employee notification

As noted above, the Goland committee reported out in January 1976, substantially coincident with direction by the Chief of Naval Material to consolidate NELC and NUC. The NELC *Calendar* ran a front-page "budget proposal" article relative to funding proposed for Navy RDT&E in its January 30, 1976 edition, with a smaller article listing new mission statements for the nine laboratories assigned to "the Chief of Naval Operations," somewhat misleading since the labs actually reported to the Chief of Naval Material.

Neither the NELC nor NUC paper reported again until their March 26, 1976 issues, when they ran identical articles with similarly worded headlines

[18] "Plan for Consolidation," II-2.

announcing to employees a “consolidation study.” Since the center commanders would provide the CNM, in three weeks, a detailed plan for the consolidation, which he had specifically ordered, it seemed no longer to be a “study.”

There was, however, another dimension to it. In addition to, or rather preceding, the NELC-NUC consolidation, the Navy was studying “‘ways and means of achieving a better focusing and integration of the closely related electronics programs’” at NELC and the Naval Research Laboratory (NRL), according to testimony of H. Tyler Marcy, Assistant Secretary of the Navy for Research and Development, to the House Armed Services R&D Subcommittee.[19]

NRL was responsible for basic research and initial development in myriad technology areas of interest and importance to the Navy. As related in the first chapter, NRL found itself overextended in the initial days of World War II, and the recently established U.S. Navy Radio and Sound Laboratory (NRSL) stepped in to evaluate early NRL efforts to develop high frequency radio communication for Navy ships at sea. Over the ensuing three decades, NRSL, succeeded by the Navy Electronics Laboratory and ultimately NELC, assumed major responsibilities for Navy electronics technology development. Marcy in his testimony advised the NELC-NRL study was undertaken due to “substantial overlap and dispersion of our in-house capabilities… relating to command control and communications and certain other electronics systems development.”

According to Marcy, the potential NUC-NELC consolidation would be affected or at least influenced by the results of the NELC-NRL study. The assistant secretary visited NUC in July and NELC several weeks later, briefed on torpedo and surveillance programs at the former, plus the Marine Mammal Program. At the electronics lab, presentations were provided on a number of surface ship, submarine, and satellite communications programs.

In mid-November, the two center newspapers ran a photo of their commanders, Captains Gilchrist and Gavazzi, cutting the ribbon on the first major achievement of consolidation: the merged Supply Department offices in NELC’s headquarters building. The February 25, 1977 issues of *Calendar* and *Seascope* (their last issues) announced, in identical stories, the consolidation of NELC and NUC, effective March 1.

---

[19] NELC *Calendar* and NUC *Seascope*, March 26, 1976, 1.

Implementation Planning Team

The effort to plan the consolidated organization, the establishment date for which was postponed several times, fell to an Implementation Planning Team (IPT), headed by NUC Commander Captain Bruce Gilchrist and closely resembling the consolidation technical committee. NELC members were Walt Mitchel, Bob Sarvis, and Myles Sheehy; representing NUC were Doug Wilcox, George Coulter, and Barney Towle. The team began meeting in August on a weekly basis to address the myriad details required in bringing together two disparate organizations.

Obviously, a key discussion point was the management organization for the consolidated center. Over the course of some months, the IPT generated a half-dozen alternatives, from a token "merger" of departments with little substantive change to establishment of a new organizational element called a "directorate." Both NELC and NUC, despite a number of reorganizations over their respective thirty-seven and ten years of operation, had "departments" as their primary major organizational element. (The Navy Radio and Sound Lab was divided originally into a Radio Division and a Sound Division, but immediately after World War II, with a new name in place, the U.S. Navy Electronics Laboratory management formed departments for research, development, and systems engineering.)

The NOTS organization, which functioned through the World War II years with only a small number of civilians, increased in size and civilian numbers almost immediately after the war, and even before 1950 had established the department as its primary senior organizational element. Over the next several decades, there would be four or five departments at China Lake, and one at Pasadena, Underwater Ordnance, headed for some years by Doug Wilcox.

With the establishment of the Naval Undersea Warfare Center in 1967, Technical Director Dr. William McLean had elevated Wilcox to a position as one of his deputies and promoted five of Wilcox's division heads to lead newly formed departments. He appointed three former NEL managers to department-level positions as well, plus he elected himself head of a new, mostly unpopulated Research and Engineering Department. In the traditional organizational paradigm, a department consisted of four to six divisions, while each division in turn was composed of four to six branches.

In the early days of Ralph Christensen's NEL, he had only one scientific department. Over the next decade, this was succeeded by two (then three, then two again) “laboratories,” which in 1970 were finally replaced by an organizational construct based on six departments.

As noted, the department was the foundation of one of the organizational structures identified for the new, as-yet-unnamed Navy laboratory, with the first proposal including eight of them. That proposal garnered no support from the IPT, which instead developed five alternatives based on a sort of “super department” titled a “directorate.”

While development of an organizational structure was a key responsibility of the IPT, they addressed a number of other issues at their weekly meetings as well.

Critical support

Early on, as reported in the minutes of the September 7, 1976 meeting, there was agreement to establish an Administrative and Technical Support Department (at the directorate level), headed by Robert Sarvis, and a Central Staff, headed by George Coulter. Sarvis and Coulter were perhaps the pre-eminent bureaucrats, a term not intended to be disparaging. While the business of the organization was RDT&E in assigned areas of technology critical to the Navy, that business could not proceed (or succeed) without the functions provided by support staffs. Lacking these functions, how do you pay your employees? Actually, how do you hire employees in the first place? If you need to send a team to a ship in the western Pacific to install hardware, who will arrange, and pay for, travel to get there? Who will purchase the hardware?

On the subject of hiring, the planning for the consolidation, originally intended to last two to three months, actually lasted seven, during which time the technical work continued and the supply line for bright, highly motivated young employees to replace those departing after lengthy federal careers was drying up. At the September 28 meeting, Doug Wilcox recommended hiring a minimum of twenty-five New Professionals before Christmas, independent of the merger. If the merger didn’t happen, he guaranteed the undersea center would cover the billets.

Fairly critical to the long-term success of the new organization was the approval, at *two* meetings in November, of Randy Riley as the acting personnel officer. At the subsequent get-together, the Public Affairs Office plan for the merger ceremony was reviewed, with a statement that PAO would oversee design of a new logo "when the new name is known."

The second meeting in December included a statement that the latest "D-Day," apparently the planned day for the establishment ceremony, would be December 15. It came and passed without incident, and without the ceremony.

Finally, in the minutes of the January 26 and February 4, 1977 meetings, the title "Naval Ocean Systems Center" appeared, without explanation of its source. One interesting possibility, based on a handwritten label ("NUSC Paper") and note attributing authorship to "Nick Pryor," is a four-page document titled "Recommendation for Establishment of a Naval Ocean Systems Center." Provenance of the document is uncertain; however, Dr. C Nicholas Pryor, Jr., was the Naval Underwater Systems Center technical director from 1975 until 1982. The document advocates development of a "real-time ocean surveillance capability, sufficient to locate and track potential threats or targets and to vector our forces to or away from them as desired." Dated April 4, 1976, it offers a proposal to form a Naval Ocean Systems Center [emphasis in original] by combining NUC and NELC into a single command headquartered at Point Loma, with an additional East Coast detachment. A proposed mission is provided, noticeably omitting the undersea weapons development, a major Naval Undersea Center product line. More than a page of the paper makes an emphatic case for transferring that work to NUSC. Stapled to the document is another four-page handwritten missive, apparently developed by Dr. Dan Andrews of NUC, refuting most of the arguments for transferring work.

At the February 10 meeting, Captain Gilchrist expressed hope for expediting the composition of the technical organization, with that hope targeting March 15. In response, at the next meeting the captain himself presented an organization based on eight technical departments. Myles Sheehy passed out copies of a two-directorate plan, Walt Mitchel proposed a four-directorate plan, and Barney Towle offered a five-directorate version. After a week to consider the various plans, the team met for the final time on February 24, with the chairman announcing their team would be dissolved upon submission of the report on the organizational alternatives. The two- and three-directorate alternatives were unanimously rejected, to be included only in cursory fashion in the report. The other three approaches would be presented in detail to the commander and technical director. As one of their final actions, IPT members conducted their own straw vote: the eight-department plan received no votes; the three NELC members and NUC commander voted for four directorates; the three NUC members favored the five-directorate approach. With that they adjourned a final time, and Myles Sheehy went off to draft the memo to the top leadership reporting on their proposals.

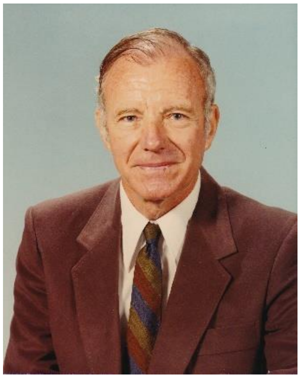
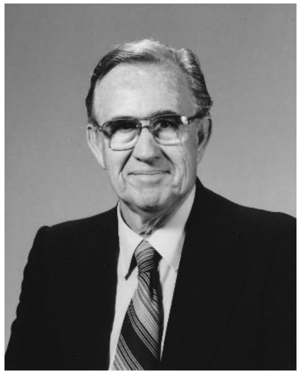
Although the IPT minutes do not reflect that, both organizations' newspapers announced, in identical statements, the establishment ceremony for the Naval Ocean Systems Center would be held March 1, on the porch in front of Building 33 where NEL/NELC traditionally staged changes-of-command. At that ceremony, guest speaker Dr. James H. Probus, the Director of Navy Labs, stated, "The consolidation of NELC and NUC combines the complementary missions of these two laboratories in support of the Navy's primary Sea Control function and strengthens and integrates the technical base for that function."

Five directorates established

The first issue of the consolidated newspaper, titled *Outlook*, was March 4, 1977, with photos of the establishment ceremony and featuring the "Big Four," the commanders and TDs of the two labs now become one. Employees had to wait for the third issue, dated March 25, to read Doug Wilcox had been selected associate technical director and there were five directorates with acting directors, who in fact became permanent directors in due time. The organizations were included only by name; the leaders got a couple of paragraphs of personal history.

This set of directorates appears to have been mainly the creation of Barney Towle. In a series of evolving thoughts over the closing months of 1976 and opening ones of 1977, he had taken pencil to graph paper and fashioned his version of a plan for the organization of the new center. Towle, it may be recalled from Chapter 9, was a Navy captain assigned to the office of the Chief of Naval Material who worked doggedly to establish a consolidated ASW command at NAS Los Alamitos in 1967. He retired from active duty after serving a final assignment as commander of the Naval Air Development Center, and almost immediately moved cross-country and went to work at the Naval Undersea Center as Air Systems Program Manager. Since NELC had no similar position, he would retain that with the establishment of NOSC. In addition to that, he would be tasked with another substantial responsibility, "In his assignment as Special Assistant he will represent top management in organizational planning among the directorates."[20] Towle's plan for the directorates, undoubtedly tweaked by a number of people, emerged over several months in this fashion:

—Command Control and Communications: This was based principally on NELC's Code 1000, which had in the matrix organization served as the "liaison" with sponsors and then handed off project assignments to the other departments. It also included former Codes 2000 (the electromagnetic work) and 3000, the Information Systems Department. Richard H. DuBois, who had headed that department, was named acting director of the C3 Directorate. A relative newcomer to the lab organization, he had previously been director of the Defense Advanced Research Projects Agency Pacific Office. Prior to that, he was a vice president of Litton Industries; his substantial claim to fame there was creation and management of the $2 billion USS *Spruance* program, the largest single program in the U.S.

Dr. Dan Andrews Charles G. Beatty Richard H. DuBois

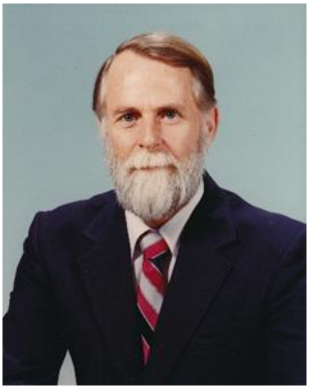
—Engineering: This organization combined two NELC departments (Engineering Sciences and Computer Science) with their opposite number at NUC, the Computer Sciences and Engineering Department. It also included the previously consolidated computer resources organization that, by virtue of the Director of Navy Laboratories selection of the UNIVAC 1100 for the primary hardware, now resided Bayside at NUC. (Somewhat immediate to the establishment of NOSC, three major "sides" were identified: the former NELC/new NOSC headquarters area as Topside; the former NUC HQ area at the waterfront as Bayside; and the area along the west-facing slopes of Point Loma

[20] Naval Ocean Systems Center *Outlook*, April 8, 1977, 1.

sliding down to the Pacific as Seaside.) Dr. Dan Andrews, NEL/NELC manager whose service dated back to the University of California Division of War Research and who transferred to NUC in the 1967 reorganization, headed this organization.

—Ocean Surveillance: This organization included technology areas experiencing exponential growth in the past several years. (An interesting handwritten document in Center archives lists various technology areas in the five directorates with funding at the time of the consolidation. Vastly overpowering the others, most of them topping out at $1-2 million, were Surface ASW at $12.7 million and undersea surveillance at $17.6 million.) Chapter 14 provided detail on expanding work in undersea surveillance and the assignment of project work in ocean surveillance, including plans for a major new building to support that work. To be added to that development were NELC's programs in surface and aerospace surveillance, including satellite communications, and electro-optics. Walt Mitchel, who served four years as NELC's Deputy TD, then headed the Command Control and Communications Programs Department, was selected acting director.

Walt Mitchel



Bill Powell

The first NOSC directors

—Undersea Weapons: Maintaining the mostly NUC weapons development, testing, and fleet engineering, this organization represented a major portion of key projects dating back to the very first days of both labs—anti-submarine warfare. It included the fire control systems and launchers, rocket development, and the various test ranges. Chuck Beatty was the more than obvious choice to manage this directorate.

—Environmental Sciences and Technology: With a number of caveats, this organization included most of the projects that Walt Mitchel's four-directorate construct had distributed among the other directorates. A memo which was developed to describe the various organizational constructs explained the alternative with five directorates

> provides greater visibility for the marine life sciences, marine mammals, and Arctic submarine systems programs [all included in this directorate]; causes less disruption of existing departments; and provides some management protection for programs and functions which might be allowed to wither if placed in the other more systems-oriented directorates.

Seemingly this included such things as basic research. Bill Powell, the NOTS Behavioral Sciences Group member whom Bill McLean had tried unsuccessfully to promote from GS-7 to GS-14 in the mid-1960s, was selected acting director for this organization. (He would be promoted in two years to GS-16.)

As noted above, the establishment of "directorates" was an unprecedented move by organizational planners. Recognizing each of those had three technical departments (and Powell's four), most fairly well established with management structure needed for program work at that level, the IPT members, in minutes from their final meeting, recommended, "We believe the directorate level should be sparcely [sic] manned; attempts to build up management staffs, special assistants, etc., should be strongly resisted as simply adding to the overhead and creating unnecessary layering of management."[21] The directors apparently "strongly resisted"; the NOSC phone book five years later listed few "staff office" types at the directorate level, most showing only the director and his secretary.

Barney Towle

[21] Minutes of the NELC/NUC Implementation Planning Team meeting, 24 February 1977, 4.

The consolidation and subsequent organizational management worked as a somewhat magical, nearly overnight "upward mobility" action across the organization. Division heads were suddenly in the vaunted position of department heads, with no long-term application, interview, and selection process. Branch heads became division heads, (usually) without a single employee added to their roster. The situation was much less pleasant when that all came crashing down less than a decade after, but that's a story for later. For now, nine former division heads and six (already) department heads reported to the five acting directors, and a ripple effect gave a substantial number of employees new and better titles.

Continuing studies/reduction-in-force

As if he did not have enough on his plate, the first NOSC Commander Captain Bob Gavazzi served on (perhaps chaired? since their output was dubbed the "Gavazzi Report") a Chief of Naval Material ad hoc group in the summer of 1977, just as his new organization was getting underway. The group was to address (additional) consolidations, contracting out, terminations, and elimination of one to two thousand Navy RDT&E personnel billets. After review of issues raised by the Office of the Chief of Naval Operations and the Assistant Secretary of the Navy for Research, Engineering, and Systems, the group was unable to find "wasteful duplication or overlap," or any simple means of manpower reduction.[22] "Vertical reductions and/or long-term functional realignment" were viewed as the "necessary" means of achieving the desired result of their charter. Of the two obvious options, retaining the present organizational structure and extant activities was viewed as saving nothing in terms of people and funding, and failing to address the major challenges.

The group recommended restructuring existing organizations, settling on five "full-spectrum" Navy R&D centers, to be assigned responsibilities for technology base, system development, and fleet/production support. Two dedicated test and evaluation centers would be the primary interface with in-service engineering organizations, training commands. fleet units, and industry partners.

---

[22] "Report of the CNM Ad Hoc Group on Functional Realignment," undated.

There is no evidence that plan was approved. However, it was painfully clear less than three months after the official consolidation of NELC and NUC that an order was promulgated from the Chief of Naval Material to reduce the number of full-time permanent positions at the new San Diego organization by a hundred and fifty. Captain Gavazzi provided the rationale several months later: 1) requirements based on Office of Management and Budget Circular A-76, which forced contracting out certain Center functions; 2) positions (already reported to higher authority) saved in the consolidation process; and 3) demands of authorized end strength.[23] Lengthy newspaper articles and Q&A features explained the procedures if voluntary retirements, a freeze on hiring, and normal attrition failed to meet the goal, with a deadline of the end of the fiscal year. As had occurred earlier in 1970s, the newspaper published editions with "38 retiring" and "21 added to retirement list" based on "early-out" incentives. Eventually the magical required end-strength number was reached with no additional mention of it.

Project work goes on

While the attention of top management understandably was focused on the mechanics of a major consolidation, technical personnel at the working level proceeded with their projects. Sponsor requirements for results necessitated continued concentration, despite organizational upheaval, on new weapon system development, as well as improvement of communication technology and greater interest in command and control, plus growing the surveillance work. It goes without saying that multi-year technical developments do not stand still or reach major milestones merely based on organizational disruptions or refinements. Volume II will discuss in detail the projects underway during the NELC-NUC merger into the Naval Ocean Systems Center, particularly those achieving major milestones. For now, we will discuss a handful of efforts to provide some technical reality to all the planning and organizing that characterized the consolidation.

The mainstay of the weapons work for decades had been lightweight anti-submarine torpedoes, and that continued. Current major laboratory work was on the Mark 46 Mod 5, titled the Near-Term Improvement, or NEARTIP. It was the latest in several generations of the Center's, and the Navy's, longest-lived torpedo.

[23] "Commander's statement on RIF," NOSC *Outlook*, June 3, 1977, 1.

The Mark 46 was developed, according to Mort Heinrich,

> … just step by step, so the Mod 0 was… the Aerojet torpedo but it had a solid propellant. Then the Mod 1 was essentially the initial torpedo of a long series of upgrades. A series of new requirements kept adding on [things like] countermeasures. So we had the Mod 2. We also had the Mod 2 because we wanted to be able to launch it from helicopters in a stand-off mode…[which required] a gyrocompass… So that became the Mod 2. Then along came countermeasures. So we had a program called the Mod 3. Except before we came up with the Mod 3, it got overcome by events, because we now suddenly had anechoic coatings on [enemy] submarines and they wanted the Mod 5. They wanted the torpedo to have increased capability and while we were at it to take care of countermeasures, etc., etc., etc. So the Mod 5 was an upgrade that incorporated some of these other steps that were about to go through.[24]

Augie Troncale, who spent his early career working torpedo development, said the Mod 5

> was primarily an extensive electronics and acoustic upgrade. One of the primary objectives was to increase the torpedo's counter-countermeasure capabilities. Our enemies are always working to disrupt, degrade, or counter the effectiveness of our weapons systems. We conversely continue to upgrade and improve the torpedo's ability to overcome those challenges and ensure we maintain our systems' operational effectiveness and capability.[25]

The Navy's expectation was to backfit Mod 5 capabilities to significant numbers of torpedoes already cruising on and above the world's oceans in Navy surface ships and aircraft: NEARTIP was intended "to counteract the ever-increasing submarine threat… This very important engineering development is directed toward a design suitable for retrofit into a sizeable portion of Torpedo Mark 46 Fleet inventory by 1977."[26]

Both NELC and NUC had pursued fairly strong programs in various aspects of surveillance, the electronics laboratory concerning itself with surface and aerospace surveillance in its satellite communications program work and its electro-optics research, and NUC heavily involved in undersea surveillance, as detailed in the previous chapter. The latter actually reflected project work dating

---

[24] Mort Heinrich oral history conducted by Tom LaPuzza, June 20, 2012, 28-29. Heinrich noted the torpedo numbering system had gotten out of hand, with numbers assigned to potential torpedoes that were never even designed. Additionally, he stated a newly numbered torpedo required congressional action, whereas a modification to an existing numbered torpedo did not.

[25] Augie Troncale oral history interview conducted by Tom LaPuzza, July 12, 2012, 17-18.

[26] "Undersea Weapons Lab Dedication," Naval Undersea Center *Seascope*, July 11, 1975, 3.

back to the very early days when the Navy Radio and Sound Lab's initially assigned major emphasis on shipboard communications shifted to include substantial research in the science of underwater acoustics. The sheer magnitude of the German U-boat threat before and in the early years of World War II forced NRSL to dedicate increased resources to the countering of that threat, often teaming with the University of California Division of War Research, which had been established for that specific purpose (see Chapter 3).

For decades, Navy Electronics Laboratory scientists like Dr. Homer Bucker continued basic research into the mysteries of acoustic energy propagation underwater. With the 1967 reorganization, those scientists transferred to the Naval Undersea Warfare Center. It was the second NUWC commander, Captain Charles Bishop, who proposed his organization seek leadership in the newest Navy technological area of undersea surveillance.

Authorized that leadership, undersea center personnel made substantial contributions to the Navy's undersea surveillance efforts, including those of the scientists assigned to the Undersea Surveillance Program Office, PME-124, at Naval Electronic Systems Command. As noted earlier, Dr. Henry S. "Hank" Aurand had transferred to NUC in the early 1970s and proposed augmenting fixed bottom arrays with mobile surveillance arrays towed by surface ships, the most successful of which was the Large Aperture Marine Basic Data Array. LAMBDA underwent substantial ocean testing, and eventually became the Advanced Development Model for the Surveillance Towed Array Sensor System (SURTASS), which we will discuss in detail in Volume II.

Fiber optic firsts

NELC was the lead lab for development of fiber optic transmission systems, demonstrating in the mid-1970s fiber optic cable could replace copper wire on internal systems in aircraft. The half-dozen years of effort culminated, shortly after the merger, in one of the first systems to be released by the new Center: the AN/FAC-1 fiber optic data transmission system.[27] According to that article, "It is the first Navy operational single fiber optical transmission system. And it is also the first fully documented, logistically supported fiber optics data transmission

[27] "NOSC develops many firsts in world of fiber optics," NOSC *Outlook*, April 8, 1977, 3.

system in the world.” Operational at the Army’s Fort Meade in Maryland, it provided twenty megabit per second data transmission rate between terminals 6,000 feet apart, without repeaters. The FAC-1 set included six transmitters and six receivers, providing six completely isolated channels for data transmission.

As related in Chapter 13, a significant event at NELC in the summer of 1974 was the groundbreaking ceremony for what was originally the Electronic Development And Test Laboratory (EDATL); later revised to Command, Control and Communications Systems Integration Test and Evaluation (C3SITE) facility; and ultimately known familiarly as Building 600. Among findings cited earlier in this chapter, the Goland Committee pointed to the “proliferation of C3 activities” through many Navy organizations, mostly uncoordinated, which prevented NELC from adequate exercise of assigned leadership. Although a significant cause was “big Navy” actions (or, perhaps, inaction), lack of appropriate facilities has already been discussed as a key factor in that challenge. Building 600 provided a substantial solution to that problem. As the months dwindled toward establishment of the Naval Ocean Systems Center, construction neared completion and small groups of people and projects began populating the structure, the initial steps in formation of that desired integrated C3 development capability.

In addition to projects related to submarine communications and C3 systems for aircraft carriers, Building 600 housed a facility for another San Diego Navy electronics organization: the Naval Telecommunications System Test Node was established in late 1976 as a section of the Naval Electronic Systems Engineering Center, San Diego. Its two dozen military personnel supported Navy participation in the Joint Tactical Communications test and evaluation program. Seeking to increase effectiveness in management and utilization of the total communications support capabilities available in the C3SITE facility, the Chief of Naval Material would transfer the test node to NOSC as a new division of the Command, Control and Communications Department on October 1, 1979.[28]

Trident Integrated Radio Room

Chapter 8 detailed the substantial contributions of the Naval Ordnance Test Station at China Lake and Pasadena to development of the first ballistic missile for

[28] “NTSTN joins NOSC,” NOSC *Outlook*, October 19, 1979, 1.

submarine launch, as well as the efforts of the electronics laboratory on Point Loma. Those efforts would continue as the Navy pushed the development of new and more capable missiles for their ballistic missile submarines, weapons, and weapon-delivery systems that required the kind of testing environment only available at the undersea center's San Clemente Island facility.

Equally important was assignment in the mid-1970s of the Point Loma electronics laboratory as lead for the essential communications suite for the newest fleet ballistic submarine (SSBN). Paul Singer, NELC electronics engineer, related,

> The boat was called the Underwater Long-Range Missile Submarine, and [its] radio room was called the Automated Communications Center (ACC). Well, after a couple of months, they had changed the name of Underwater Long-Range Missile Submarine to Trident, and the ACC became the Integrated Radio Room.[29]

Singer was brought into Dick Eastman's FBM Communications Program Office, discussed in Chapter 13, and given a specific assignment: "They needed someone to trace a hypothetical signal that would be received by a submarine antenna, through the conditioning units, to the receivers and out to the printer." His tasking was to track very low frequency (VLF) radio waves received by an SSBN antenna and ensure these critical messages would be received and routed properly so the submarine crew could take appropriate action. There were others in the program office involved in similar projects, he said:

> It was primarily an effort to do sizing, in terms of determining what the weight, size, power, air conditioning requirements would be for that particular sub-system. And that was put together and it eventually led to a specification, which led to a competitive contract for the radio room, my sub-section being one of about seven sub-systems in the radio room. It was deployed on the [USS] *Ohio* [(SSBN-726)] Trident submarines.

The radio room itself was developed under Navy contract, with the first contractor delivery ten months after NOSC was established. Assuming the primary role that NELC had been executing for several years, "NOSC performed conceptual design and is serving as lead laboratory."[30] NOSC also directed the test and evaluation team.

---

[29] Paul Singer oral history interview conducted by Tom LaPuzza, November 8, 2012, 6-7.
[30] "NOSC Annual Report CY 1977-78 (U)," NOSC TD 177 of 1 March 1979, 75-77.

Carrier communications

NELC was involved in communications developments from deeply submerged submarines to satellites, and substantial efforts in between. One of the latter, established to benefit Navy aircraft carriers, was the flight deck communication system, a long-standing effort at the electronics lab. Initial work in this area was conducted in the mid-1950s, based primarily on detailed study of the detrimental effects of noise by Dr. John C. Webster.[31] As one of the NELC Human Factors and Engineering Division's researchers on sound reduction, Webster was instrumental in the development of the SRC-22V Flight Deck Communication System, used on all the Navy's carriers of that era. It enabled "complete two-way radio interchange between the air officer, the aircraft handling officer and all mobile supervisory personnel on the flight deck."[32]

As a follow-on effort, Webster teamed with Dale Gibson and Fred Henry to develop the Man-on-the-Move Communications System (MOMCOMS) in the early 1970s. It provided "message-secure multi-channel wire-free links and good speech intelligibility in the presence of intense acoustic noise."[33]

The Computer Revolution

When Volume II of this history appears, some years from now, its second or third chapter, after the one(s) expanding on the consolidation of NELC and NUC into the Naval Ocean Systems Center, will be titled something like "The Computer Revolution." It will discuss in some detail how NOSC from its earliest days, and in fact even before that time, played a significant role in the vast changes in the world occurring shortly after the middle of the twentieth century, changes perhaps paralleled only by the Industrial Revolution and the advent of the automobile.

---

[31] In one of the early examples of cooperation preceding the establishment of NOSC, Webster worked with the undersea center's Robert S. Gales, Dr. Robert W. Young, Halcyon Morris, and Dr. Roy G. Klumpp on the Acoustical Society of America's community education program in noise pollution and control.

[32] : "Sounds of the '70s… how do we cope with them?" Naval Electronics Laboratory Center *Calendar*, September 25, 1970, 2

[33] "Code 1290 develops system for shipboard communications," NELC *Calendar*, April 27, 1973, 3.

As we have already discussed several times in this history, the use of computer technology played a substantial role in the workings of the electronics and weapons organizations. Those included such disparate functions as paying employees and testing torpedoes, processing returns from submarine sonars and tracking multiple air targets.

The power of the individual computer was magnified exponentially by the linking of those machines into networks:

> Just as the telephone, the telegraph, and the printing press had far-reaching effects on human interconnection, the widespread utilization of computer networks which has been catalyzed by the ARPANET project represents a similarly far-reaching change in the use of computers by mankind.[34]

The project referred to was the first significant attempt to network computers, initiated and directed in the late 1960s by the Defense Advanced Research Projects Agency (DARPA), a DoD agency which, according to its website, "For sixty years… has held to a singular and enduring mission, to make pivotal investments in breakthrough technologies for national security."

Foreseeing the potential power of computer networking, DARPA (whose acronym over time would see the "D" deleted and reinstated) initiated a program termed "Resource Sharing Computer Networks." With contractor support, the agency sought "1) To develop techniques and obtain experience on interconnecting computers in such a way that a very broad class of interactions are possible, and (2) To improve and increase computer research productivity through resource sharing."[35]

The result, several years later, was the ARPANET. According to a fairly extensive and inclusive information brochure,

> The ARPANET is an operational, resource sharing inter-computer network linking a wide variety of computers at Defense Advanced Research Projects Agency (DARPA) sponsored research centers and other DoD and non-DoD activities in CONUS [Continental United States], Hawaii, Norway and England. The ARPANET originated as a purely experimental network in late 1969 under a research and development program sponsored by DARPA to advance the state-of-the-art in computer internetting. The network was designed to provide efficient

[34] Defense Advanced Research Projects Agency, "A History of the ARPANET: The First Decade," 1 April 1981, I-2. One can't help wonder how that network fit the definition of Samuel Johnson in his 1755 *A Dictionary of the English Language*: "Network: Any thing reticulated or decussated, at equal distances, with interstices between the intersections…"
[35] ARPANET history, II-2.

> communications between heterogeneous computers so that hardware, software and data resources could be conveniently and economically shared by a wide community of users.[36]

Having made its "pivotal investment" and guided it through several years of development, DARPA considered it reasonable to transfer the effort to the Defense Communications Agency to manage in 1975.

The original "network" included four nodes: at UCLA, Stanford Research Institute, UC Santa Barbara, and the University of Utah. In late 1975-early 1976, Node 3 at UCSB was transferred, with its number, to the Naval Undersea Center. Ron Broersma, whose computing technology contributions to the Center, Navy,

Ron Broersma

and DoD would be monumental, arrived as a New Professional at NUC in the class of 1976. In an interview four decades later, he talked about having that network connection turned over to him to manage:

> … I was introduced to this thing called the ARPANET, and there was a little communications room… and there was this rack of equipment, and that was the IMP [Interface Message Processor], and there was another *massive* rack which was the modems that talked to the other

[36] Defense Communications Agency, "ARPANET Information Brochure," 13 March 1978, 1.

> computers. And a fifty-kilobit modem was like this massive piece of equipment that ran over the telephone lines, over the AT&T telephone lines in those days. And … I got talked into becoming the node site coordinator. So it's like, 'This is now yours.' And along with it we had a little PDP-11 computer that was running an operating system called ELF at the time; this was before UNIX. And so I could see the possibilities. I converted ELF into UNIX. I got the software… that let us run TCP/IP on top of UNIX, on top of this PDP-11, connected to the ARPANET, and so we actually had a computer on the ARPANET and eventually that front-ended the UNIVAC 1100, which is what was really supposed to be on the ARPANET and why I was put there in the first place.[37]

In an email response to a question about the interview quote, Broersma advised ELF, essentially the German word for "eleven," was an operating system developed at Santa Barbara in 1975 before the node was transferred to NUC.[38] ELF was developed as an ARPA-sponsored project for an operating system compatible with the original network protocol, titled "NCP" (Network Control Program), which was employed prior to the invention of Transmission Control Protocol/ Internet Protocol (TCP/IP). It was a short-lived development that was replaced fairly quickly by Unix, according to Broersma.

Growing into the role of network admin, Broersma provided the Center, first the Naval Undersea Center and very shortly thereafter the Naval Ocean Systems Center (NOSC), with connection capabilities other organizations would envy, once they were able to understand the import of them. In those days, as the organizational merger under discussion in this chapter began to take shape, that early lead position was invaluable:

> Node Three was interesting for a number of reasons… it was significant in that we had one of the very early ARPANET nodes. Inside of the Navy or DoD community, we had the one with the lowest number… it was kind of fun having one of the very small numbers and then when we converted to MILNET we became ten-dot-zero-dot-zero-dot-three, so we were always first in a lot of the lists. And that was nice.[39]

As will be discussed in Volume II, the advent and burgeoning of electronic mail taking advantage of that network would provide NOSC a very powerful and leading position in the computer revolution.

---

37 Ron Broersma interview conducted by Tom LaPuzza, May 27, 2016, 55-56.

38 Ron Broersma email to Tom LaPuzza, March 9, 2021. The paper cited in the email was David L. Retz and Bruce W. Schafer, "Structure of the ELF Operating System," presented at the National Computer Conference in 1976. In a footnote, the authors advise about the etymology of "ELF" and stated it was "somewhat germane to the naming of IMPs [Interface Message Processors] in the ARPA network."

39 Ron Broersma interview, 57.

Andy Juhasz

"I guess you could say I've had a fairly destructive career. Some people say I've sunk more tonnage than most submarine skippers," quipped Andy Juhasz in his retirement story.[40] Targets he "addressed" in his career as a Center weapons tester included two submarines, five destroyers, a cruiser, a number of tanks, two missile assembly buildings, and twenty drones, including a B-29 bomber.

A World War II Marine Corps veteran, Juhasz served as a forward observer directing Navy gunfire and Marine artillery fire; he saw action at Guadalcanal, Bougainville, Tinian, Saipan, Guam, and Iwo Jima.

Accompanying a buddy seeking a job at the relatively new Naval Ordnance Test Station at China Lake, he decided to apply as well, and began his long weapons testing career on the Lark missile. Subsequently he participated in test and evaluation of the Zuni rocket; Terrier, Tartar, and Talos missiles; and the Anti-Submarine Rocket.

"We also fired Dr. McLean's first Sidewinder on the ground ranges," he said.

Recalled to active duty in 1951, he spent only a short time at Camp Pendleton before developing an interest in the misfiring of the Corps' 105-mm howitzer. Calling on his weapons testing experience, he returned to China Lake, where he successfully identified and corrected the malfunction causing premature detonation of the howitzer shells.

Following his discharge, he spent another half-dozen years on the China Lake desert weapon ranges. In 1957 he executed "one of the best decisions I ever made," and transferred to the NOTS Pasadena Annex with its sea test ranges at San Clemente Island and Long Beach. The timing was such he was able to participate in testing of the Navy's first submarine-launched Fleet Ballistic Missile (FBM), Polaris, including the first live launch of the missile. He was subsequently involved in the testing of the other FBMs, Poseidon and Trident.

[40] "45 years dedicated to weapons testing," NOSC *Outlook*, July 8, 1988, 3.

Andy Juhasz

Selected to head the Fleet Engineering Department's Range Branch in 1969, he spent more than a decade managing that largest branch of the Center, boasting similar numbers of personnel to a typical division. In 1982 he was promoted to head one of those himself, the Test Division, where he spent another six years overseeing a substantial array of facilities, ranges, and specialized testing and documentation equipment. Dr. Frank Gordon, who preceded Juhasz as head of the Test Division and was later his department head, recalled, "I appreciated Andy's positive attitude. I remember [him] as someone who would always say he, and his group, could do just about anything."[41]

His division's success was a testament to his own, and the example he set was not merely on his immediate subordinates. The only known Center employee to

[41] Dr. Frank Gordon email to Tom LaPuzza, September 13, 2019.

rise from technician to department head credited Juhasz with influencing him to achieve excellence:

> Andy was an inspiration to me. He was a strong leader who worked his way up the career ladder with hard work and ended up leading a challenging and diverse division. His leadership and ground breaking rise through the ranks helped people like myself attain high-level positions in the Center in the future years.[42]

[42] Augie Troncale email to Tom LaPuzza, September 11, 2019.

To the future

This volume, the first of two planned, has attempted to characterize and summarize the history of the Navy laboratory currently (2020) known as Naval Information Warfare Center Pacific, from its beginnings to a logical mid-point, the merger of the electronics and weapons organizations into the Naval Ocean Systems Center in 1977. Looking back on this first volume, the reader with good recall might be able to remember several score of programs and projects in more than a dozen widely varying areas of technology. Substantially more than a hundred individuals have been cited for contributions large and small to these efforts. Despite those numbers, this volume has barely scratched the surface of the technical achievements of the Navy lab centered on Point Loma in San Diego, and, more critically, has only minimally covered the people who were responsible for those achievements.

Volume I was designed to discuss origins and early development of the Navy's first two, and then three, research and engineering laboratories on the West Coast. Inclusion of the California universities that contributed substantially to the effort was essential. With the consolidation of the Naval Electronics Laboratory Center and the Naval Undersea Center, the first phase of this history concludes. Volume II will pursue the second phase, as the single organization, despite growing pains in that role, moves into the future.

A toast to the future Naval Ocean Systems Center is shared by (l-r) NOSC Technical Director Dr. Howard L. Blood, Director of Navy Laboratories Dr. James Probus, and NOSC Commander Captain Robert R. Gavazzi.

NRSL

U.S. NAVY ELECTRONICS LABORATORY
nel
A BUREAU OF SHIPS FACILITY

DEPARTMENT OF THE NAVY
NAVAL ORDNANCE TEST STATION

NAVAL UNDERSEA CENTER
nuc
SAN DIEGO, CALIFORNIA

NOSC

NRaD

SPAWAR
Systems Center
San Diego

SPAWAR
Systems Center
PACIFIC

Naval Information
Warfare Center
PACIFIC

APPENDIXES

A: Point Loma Navy Laboratory Chronology to 1977

September 28, 1542	Explorer Juan Roriguez Cabrillo hands at Ballast Point on Point Loma, claims possess for the king of Spain, and names the discovery San Miguel.
November 10, 1602	Explorer Sebastian Vizcaino enters the harbor and renames the area San Diego de Alcala'.
July 29, 1846	The sloop USS *Cyane* anchored off Ballast Point, claiming the port and area around it for the U.S.
February 26, 1852	President Millard Fillmore's Executive Order set aside 1,300 acres of the Point Loma peninsula as a military reservation.
February 28, 1870	The U.S. Army took possession of Ballast Point and the Point Loma Military Reservation.
June 1, 1940	The U.S. Navy Radio and Sound Laboratory, the original command to which NIWC Pacific traces its heritage, was established by Secretary of the Navy Frank Knox. Headed by Commander Jennings B. Dow, the staff was his secretary, two Navy chief radiomen, and two civilian radio engineers.
April 26, 1941	The University of California Division of National Defense Research (later Division of War Research) was established by the National Defense Research Committee as one of two laboratories contracted to support the Navy's ASW efforts. It was co-located with the U.S. Navy Radio and Sound Laboratory.

November 8, 1943	Secretary of the Navy Frank Knox established the U.S. Naval Ordnance Test Station at Inyokern, California. Station Commanding Officer Captain Sherman E. Burroughs had an initial staff of Navy uniformed officers and no civilians.
December 3, 1943	Most probable date for the first weapon test at NOTS of 3.5-inch rockets tested for fuze functioning characteristics against land targets. Weapons development and testing was done almost exclusively by civilians from the professional staff of California Institute of Technology in Pasadena.
February 15, 1944	First U.S. aircraft rockets were fired in the Pacific theater, at Bougainville. They were NOTS-developed 3.5-inch rockets.
November 29, 1945	U.S. Navy Radio and Sound Laboratory was renamed U.S. Navy Electronics Laboratory.
June 30, 1946	The University of California Division of War Research was disestablished. Most of its projects were turned over to the U.S. Navy Electronics Laboratory.
May 7, 1948	The Variable Angle Launcher was dedicated at Morris Dam.
May 8, 1948	The Michelson Laboratory at China Lake was dedicated, named for the first American Nobel Prize winner, a naval officer.
July 1, 1948	The NOTS Pasadena Annex was established. Employees of the General Tire and Rubber Company in Pasadena were converted to Navy civilian employees.

April 28, 1949	The property of Navy Radio Station Point Loma was transferred to the U.S. Navy Electronics Laboratory.
June 30, 1949	The property of the Public Health Service Quarantine Station was transferred to the U.S. Navy Electronics Laboratory. The area includes the present-day Dolphin Facility, housed in one of the station's original four buildings.
February 26, 1951	The Army transferred much of its property west of Cabrillo Memorial Drive to the Navy, placing the land around the Antenna Model Range under the jurisdiction of Navy Electronics Laboratory.
January 1, 1954	Dr. F.N.D. Kurie succeeded Dr. Joseph Maxfield as the NEL senior civilian. Maxfield's title of superintending scientist was changed to technical director when Kurie took over the position.
June 19, 1958	An inert Polaris missile was launched underwater by NOTS test personnel at the Pop-Up facility at San Clemente Island for 35 news reporters. The missile, fired using compressed air, flew 100 feet into the air before falling back as planned into safety nets.
August 3, 1958	USS *Nautilus* (SSN-571), steaming under the polar ice cap, passed under the North Pole. Aboard, as ice pilot, was Navy Electronics Laboratory's Dr. Waldo Lyon, the world's foremost expert on the Arctic.
March 17, 1959	USS *Skate* (SSN-578) surfaced through the ice at the North Pole, with Navy Electronics Lab's Dr. Waldo Lyon aboard as ice pilot.

1960s

January 23, 1960	The bathyscaph *Trieste*, operated by the Navy Electronics Laboratory, descended 35,800 feet to the bottom of the Challenger Deep in the Mariana Trench, the very deepest point of the ocean.
February 9, 1960	USS *Sargo* (SSN-583) surfaced at the North Pole during a 31-day, 6,000-mile voyage under the polar ice cap, in the first winter deployment to the Arctic. The sub, with NEL's Dr. Waldo Lyon aboard as ice pilot, surfaced 20 times, under "the worst imaginable conditions."
April 14, 1960	First live underwater firing of a Polaris missile, conducted by the Naval Ordnance Test Station Pasadena Annex at San Clemente Island.
June 21, 1960	The Anti-Submarine Rocket (ASROC), developed by the Naval Ordnance Test Station, was revealed during a demonstration firing from USS *Norfolk* (DL-1) for news media near the Florida Keys.
July 20, 1960	USS *George Washington* (SSBN-598) launched the first fleet-fired Polaris missile, three months after the first successful underwater launch at San Clemente Island by NOTS Pasadena personnel.
August 24, 1960	National headlines highlighted the voyage of USS *Seadragon* (SSN-584), the first sub to navigate the Parry Channel through the Canadian archipelago (the famous "Northwest Passage"). The sub continued on to the North Pole, the Bering Sea, and Hawaii. Aboard as ice pilots were NEL scientists Dr. Waldo Lyon and Art Roshon.

August 26, 1960	The Navy revealed its new command and control capability, the Naval Tactical Data System, on which NEL had performed the system integration.
October 22, 1962	NEL's Dr. Robert S. Dietz presented his "spreading sea floor" theory to the American Association of Petroleum Geologists.
June 1963	NEL's bathyscaph *Trieste* began dives in the Atlantic, locating the wreckage of USS *Thresher* (SSN-593) in 8,400 feet of water. On August 28 crewmembers used its mechanical arm to recover wreckage fitting positively identifying the sub.
October 1, 1963	Publishing in *Applied Physics Letters*, a group of NEL physicists led by Dr. Erhard Schimitschek announced the development of the world's first liquid laser to produce a visible light beam.
July 10, 1964	The NEL Transducer Evaluation Center was dedicated. During the ceremony Charles Green received a patent for his design. On January 8, 1965, Green received a Presidential citation for economy achievement for his facility design.
August 28, 1965	SEALAB II, an underwater living experiment, began off Scripps pier in La Jolla at a depth of 205 feet. Both NEL and NOTS participated, the latter providing the dolphin Tuffy to deliver mail, tools, and messages to the habitat, proving dolphins could work untethered in the open ocean.
April 7, 1966	The Naval Ordnance Test Station's Cable-controlled Underwater Recovery Vehicle (CURV I) played a critical role in recovery of a hydrogen bomb lost in the Mediterranean Sea near Palomares, Spain.

May 1967	A month ahead of schedule, NEL personnel delivered the Message Processing and Distribution System, the first computerized system for handling shipboard internal communications, for installation on USS *Oklahoma City* (CLG-5).
July 1, 1967	Substantial reorganization of Navy research and development centers resulted in renaming Navy Electronics Laboratory the Naval Command Control and Communications Laboratory Center and creation of the Naval Undersea Warfare Center from the Pasadena Annex of the Naval Ordnance Test Station and the Underseas Technology Directorate of NEL. NOTS at China Lake became the Naval Weapons Center.
July 21, 1967	*Calendar* announced NEL's name, changed July 1 to Naval Command Control Communications Laboratory Center, would be Naval Electronics Laboratory Center for Command Control and Communications (shortened to NELC).
August 2, 1967	First underwater launch of a Poseidon missile test vehicle by the Naval Undersea Warfare Center at its San Clemente Island range.
March 15, 1968	NELC began offering on-site courses during working hours in FORTRAN programming and computer fundamentals "for personnel with no previous background in the field."
June 6, 1968	USS *Dolphin* (AGSS-555) was launched, the Navy's first submarine designed as a sea-going laboratory. Personnel from NEL (later transferred to NUWC) played key roles in lobbying for such a research platform and specifying its mission requirements.

July 1, 1968	Navy directed relocation of the Naval Undersea Warfare Center from Pasadena to San Diego. Eight months later, NELC transferred 35 acres of its property to NUWC, including the Arctic Submarine Laboratory, its waterfront area, and the Transducer Evaluation Center.
September 20, 1968	NUWC announced establishment of its new Hawaii Laboratory on the Marine Corps Air Station at Kaneohe Bay.
February 17-18, 1969	Double disasters struck the SEALAB III undersea habitat off San Clemente Island as aquanaut Barry Cannon died of cardiac arrest and leakage of the helium-oxygen atmosphere inside required an emergency lift of the habitat.
March 28, 1969	The undersea lab's name was changed officially from Naval Undersea Warfare Center to Naval Undersea Research and Development Center. Headquarters moved from Pasadena to San Diego concurrent with the name change. The Pasadena and Hawaii locations became "laboratories."
June 6, 1969	NELC's newspaper *Calendar* reported on successful UHF satellite communications as a message was relayed from the Center's Point Loma transmitter to USS *Providence* (CLG-6) via the Lincoln Experimental Satellite Number 6.
July 1, 1969	A new accounting system went into effect at the Naval Electronics Laboratory Center, Naval Undersea R&D Center, and other R&D activities. Called the Navy Industrial Fund (NIF), it required Navy labs to operate financially in a manner somewhat similar to private business, but without profit or loss.

1970s

November 4, 1970	Cynthia, an Atlantic bottlenose “porpoise,” gave birth to a 25-pound calf at the Naval Undersea R&D Center’s facility at Pt. Mugu, the first marine mammal birth for the Center. Based on standard veterinary practices, mother and calf were left alone for a lengthy period, after which it was determined Pinger was a male.
November. 7, 1970	USS *Dolphin* (AGSS-555) arrived in San Diego for the first time since its commissioning and tied up at the Naval Undersea R&D Center pier.
August 6, 1971	NELC became the first Navy lab to acquire the AN/UYK-7 shipboard computer system, to facilitate its support of current systems and development of future ones.
October 1, 1971	NURDC’s *Seascope* reported on an object recovery capability called Quick Find, employing California sea lions with a depth capability of 500 feet.
January 12, 1972	NUC’s Marine Life Sciences Laboratory was dedicated; it provided better acoustic conditions than the previous facility at Pt. Mugu for marine mammal research.
January 28, 1972	NELC’s *Calendar* announced plans to set up an “ultra-clean” room in a former 16-inch gun emplacement on Pt. Loma for Large-Scale Integration work in microelectronics.
June 9, 1972	The words “Research and Development” were dropped officially from the undersea center’s title.

July 17, 1972	The Navy's first Environmental Protection Award was presented by Navy Secretary John Warner to NUC for an environmental study of Pearl Harbor conducted by the Center's Hawaii Lab.
September 1972	A tape recorder believed to be the first magnetic tape recorder manufactured in the U.S. was donated to a museum in Hollywood being established by the Audio Engineering Society. The Rangertone serial number 0001, purchased by the Navy in 1948, had been in use at NEL and NUWC/NUC until just before its donation.
September 1, 1973	NUC's Cable-controlled Underwater Recovery Vehicle (CURV III) played a pivotal role in the rescue of the *Pisces* III submersible with two men aboard from a depth of 1,375 feet in the Irish Sea off Cork, Ireland. The rescue was accomplished in what was described as a Sea State Six.
May 3, 1974	NUC's Pasadena Laboratory was formally disestablished, with the programs and people consolidated at its San Diego headquarters.
May 17, 1974	Building 1 Bayside was dedicated as the NUC administration/laboratory building. On September 29, 1976, it was renamed in honor of former Technical Director Dr. William B. McLean.
May 17, 1974	The Message Processing and Distribution System aboard USS *Nimitz* (CVAN 68), designed and developed by NELC, processed its first real-world message traffic.
March 19, 1976	The Navy announced plans to study the possible consolidation of NELC and NUC.

April 14, 1976	NELC-developed Submarine Satellite Information Exchange System passed a major milestone when the Atlantic Fleet Communication System transmitted the first message between Submarine Force Atlantic and USS *Batfish* (SSN-681).
September 10, 1976	An SH-2F helicopter landed on NUC's Stable Semi-submerged Platform *Kaimalino* in Hawaiian waters, making the 89-foot craft the smallest air-capable platform in the Navy.
December 20, 1976	Navy personnel in Cutler, Maine, activated the power for the VERDIN submarine broadcast system, which vastly improved communications to submarines, aircraft, and selected shore stations. NELC/NOSC personnel played a major role in all aspects of design, development, and implementation of the system.
February 24, 1977	NUC conducted a Tomahawk Cruise Missile test at San Clemente Island in which the missile made its first transition from boost flight to cruise flight.
March 1, 1977	With the consolidation of the Naval Electronics Laboratory Center and the Naval Undersea Center, the Naval Ocean Systems Center was established.

B: Organization Awards (1940-1977)

The value of an organization, and of its employees, is reflected to a substantial degree in the awards it and they receive. Listed below are many, but certainly not all, of the major awards presented during the first thirty-seven years of the Naval Information Warfare Center Pacific history.

President's Medal for Merit

Awarded between 1944 and 1952 at the discretion of the President, it was the highest U.S. award for a civilian at the time.

Dr. William A. Fowler
Dr. Gaylord P. Harnwell
Dr. Charles Christian
LauritsenDr. Max Mason
Dr. Clark Millikan
Dr. Robert Millikan
Dr. Linus C. Pauling
Dr. Bruce H. Sage
Dr. Richard C. Tolman

President's Certificate of Merit

Dr. Thomas Lauritsen

Distinguished Civilian Service Award

The nomination form describes, "This is the highest award which the Secretary of the Navy may confer upon a civilian employee of the Department of the Navy. Bestowal is on a highly selective basis to employees who have distinguished themselves by extraordinary service or contributions of major significance to the Department of the Navy. The achievements or service must be truly exceptional…" Similar requirements, but at progressively higher levels, attend the Department of Defense and Presidential Distinguished Service awards.

Dr. Waldo K. Lyon

His essential contributions to the Navy's ability to operate its submarines in the Arctic earned him a Department of the Navy Distinguished award in 1955, one from the Department of Defense in 1956, and a third from President John F. Kennedy in 1962. He is also credited with ten Navy Unit Commendations and two Presidential Unit Citations.

Dr. William B. McLean

His critical role in inspiration for and development of the Sidewinder air-to-air missile earned him an unusual award from President Eisenhower in 1958, apparently differing from but certainly on a par with a Presidential Distinguished. It was characterized as "a special gold medal Presidential Award… for 'exceptionally meritorious civilian service' to the government." His decades of service as a nationally recognized leader of research and development merited him the Navy Distinguished award immediately prior to his retirement in 1974.

Dr. Andreas Rechnitzer

His leadership of Project Nekton, culminating in the "Deep Dive" of the bathyscaph *Trieste* to the bottom of the deepest ocean depth, resulted in a Presidential Distinguished award, presented by Dwight D. Eisenhower in 1960.

Arthur H. Roshon

He received the Navy award in 1960 for his participation in and outstanding contributions to the Arctic cruise of USS *Seadragon* (SSN-584), including his leadership of design and development of an iceberg detection device that made the cruise possible. He was also the recipient of several unit citations.

Bill Powell

His 1973 Navy Distinguished award resulted from his leadership in the creation of the Navy Marine Mammal Program and the operational deployment of the first marine mammal system.

Navy Superior Civilian Service Award

The second highest award to honor Navy civilians, "It is to be granted only to those employees who have distinguished themselves through contributions of major significance and/or extraordinary service to the Navy. The achievements or service must be exceptional in value…"

Dr. Robert F. Dietz

Presented June 10, 1960 by the Chief of Naval Research, former NEL Commanding Officer Rear Admiral Rawson Bennett, for his foundational advocating of the value to the Navy of the bathyscaph *Trieste* and his involvement in its utilization to support Navy programs.

Dr. Jack H. Slaton

Presented May 1965 by the Bureau of Weapons for his development of the REVEL (REVerberation ELimination) acoustic homing system for the Mark 46 Mod 0 torpedo.

Bill Bunton

The NEL diver/photographer was a member of one of the dive teams for SEALAB II in the summer/fall of 1965. His performance of his aquanaut duties, which included diving to the project depth limit of 370 feet (one of only two), earned him the Superior in January 1966.

Dr. Marguerite M. "Peggy" Rogers

Cited in July 1966 for her management of NOTS China Lake conventional free-fall weapon development program. She was also the first woman department head at China Lake.

Howard R. Talkington and Devirl A. Kunz

Awarded in June 1967 for their leadership roles in the recovery of a hydrogen bomb from the floor of the Mediterranean Sea by the Cable-controlled Underwater Recovery Vehicle. Talkington would receive a second Superior in 1993, based on his entire career "as a mentor of ocean technology and engineering," and a Navy Meritorious in 1982 for assuming leadership of Central Staff while simultaneously heading one of the Center's technical departments.

Charles S. Manning

Presented in March 1970, his award reflected his leadership of NEL/NELC efforts in development of the Navy Electronic Warfare System and the Naval Tactical Data System, and his mentoring of substantial numbers of scientists and engineers reporting to him.

Douglas J. Wilcox

His many outstanding years of service in top management earned Wilcox three of the awards. The first, a surprise at a NUC retiree luncheon in 1975, cited his seven years as Associate Technical Director and six months as acting TD. He was cited again in 1982 for service as NOSC Associate TD, and in 1987, shortly after his retirement, for major contributions to the successful NUC-NELC merger into NOSC, his dedicated support of the New Professional program, and his work on the Demonstration Project.

Dr. Howard A. Wilcox

Presented at his retirement in 1984 for his vast variety of achievements in rocket science and aerodynamics, electronics, navigation, and ocean engineering, and his prescient vision of the essential importance of solar energy.

Navy Meritorious Civilian Service Award

Defined in later Center newspapers as "recognition of service or contributions which have resulted in high value or benefit to the Navy," the Navy Meritorious is the third highest award the service can give to a civilian.

Dr. J.P. Maxfield

He spent only five years at the U.S. Navy Electronics Laboratory, 1948-1953, as superintending scientist. He was presented m the award the month before retirement.

Dr. A.B. Focke

The Associate for Research of the U.S. Navy Electronics Laboratory, he was presented the Navy Meritorious in 1953 for his outstanding work in physics. He'd received one previously while employed by the Navy Bureau of Ordnance.

Lloyd Maudlin

Initially employed at NOTS Pasadena while still a student, he ran the Navy's first simulation on an analog computer-driven flight table, evaluating a Mark 37 torpedo. His pioneering efforts earned him a Navy Meritorious in 1953, only his second year as a federal employee.

Duane Mack

Cited with Navy Meritorious in May 1956 for his development of the NOTS "Charlie Range," which provided a test range with such capability that it served as a model for several other Navy and Marine ranges (Navy Fallon, Nevada; MCAS Cherry Point, N.C.)

Ted Gautschi

Navy Meritorious in August 1956 for his project management of two torpedo programs. Several months earlier he had been awarded a Sloan Fellowship.

Carney D. Brewer

Her plan benefitting needy families, Operation Santa Claus, was a major holiday project for the Pasadena Annex and earned a Navy Meritorious in 1957. A decade later, as Carney Kraemer, she was the undersea center's first public affairs officer.

Luke Osborn, Howard Lynch, Charles Bradley

Trio of San Clemente Island Public Works employees who entered a burning building after an explosion to rescue survivors. They found one victim, whom they pulled out of the building, but he had died. Two re-entered the building, which was in danger of another explosion, to ensure no one else was inside. Navy Meritorious awards were presented to them in March 1961.

Ralph Gastellum

Received in 1962 for quick action containing a fire in a major NEL building near its headquarters, cooling potentially explosive chemicals with a fire extinguisher.

China Lake

The August 16, 1963 *Rocketeer* reported 237 employees received recognition for the highly successful visit of President John F. Kennedy, seven of whom received the Navy Meritorious: Robert A. Appleton, J.T. Bibby, *Albert B. Christman*, Ted R. Bates, *William H. Hampton*, William N. Sorbo, Henry H. Wair. (Awardees listed in italics eventually became employees of the Point Loma Navy laboratory.)

X. Martin Smith

Presented in December 1964 for his writing and monitoring of technical contracts at NOTS China Lake, including pioneering of technical engineering audits

Ralph W. Middleton

Meritorious presented in June 1965 to the NOTS computer programmer blind from birth, who translated standard computer programming texts into Braille, and principally for "exceptional contributions" to the President's Commission on the Employment of the Handicapped

Earl G. Loomis

Navy Meritorious received in January 1966 for his contracting expertise in program management for the NOTS Weapons Development Department

Joe Berkich, Ed Carpenter

Navy Meritorious presented in June 1966 for their contributions to SEALAB II: Berkich for modifying and outfitting the staging vessel (see vignette for Chapter 12) and Carpenter for the "lowering system" that placed the habitat on the sea floor

Owen S. Lee

A NUC oceanographer, his award in July of 1973 was based on his service as Navy Science Assistance Program science adviser to Commander, ASW Force, U.S. Sixth Fleet.

Garland L. "Gar" Hoffman

As he was retiring in June 1975, cited for efforts in the NUC Employee-Management Relations Office he managed, supporting both management and employees in resolving personnel issues.

Cy Martens

Civilian assistant to the NUC Public Works Officer, he was cited in February 1977, particularly for his substantial support of construction, alteration, and installation of work spaces for personnel transferring from Pasadena.

Naval Ordnance Test Station L.T.E. Thompson Award

Instituted in 1956 in honor of the first NOTS technical director, Dr. Louis Ten Eyck Thompson, it represented "highest recognition for outstanding individual achievement." (Awardees listed in italics transferred to the undersea center in 1967 or later.)

1956

Dr. L.T.E. Thompson (for his essential role in the establishment and development of NOTS)

Dr. William B. McLean (for Sidewinder)

1957

Rear Admiral Sherman E. Burroughs, Jr., USN

Commander John O. Richmond, USN (Retired)

Dr. Bruce H. Sage

Dr. Gilbert B.L. Smith

Captain Levering Smith, USN

Haskell G. Wilson

1958

Captain Frederick L. Ashworth, USN

Rear Admiral John C. Hayward, USN

Dr. Howard A. Wilcox

1960

Dr. Ronald A. Henry

Edward W. Price

1961

Dr. Frank E. Bothwell

Francis M. Fulton

Leonard T. Jagiello

Franklin H. Knemeyer

Dr. William S. McEwan

Lawrence W. Nichols

Douglas J. Wilcox

1962

W.F. Cartwright

Captain Frederick A. Chenault, USN

Dr. Glover S. Colladay

Duane W. Mack

Jack H. Slaton

Vice Admiral Paul D. Stroop, USN

Dr. Newton E. Ward

1964

Charles G. Beatty

Dr. Lohr A. Burkardt

Dr. William J. Finnegan

Captain William J. Moran

1965

John Pearson

Dr. Marguerite M. Rogers

1966

Jack A. Crawford

Dr. William R. Haseltine

James H. Heflin

Dr. I.E. Highberg

Naval Ordnance Test Station William B. McLean Award

Awarded for the first time in January 1968 to Dr. McLean himself, for "outstanding creativity as evidenced by patents presented to him"

NEL/NELC Commanding Officer and Director's Award

These awards were initiated/sponsored by the Bureau of Ships and presented at all BuShips laboratories, with laboratory awardees eligible for the more prestigious bureau award.

1961: Dr. Maurice Halstead for conception and development of NEL International Algorithmetic Compiler

1962: J.S. Hickman for ASW transducers

1963: Dr. Ernest R. Anderson for developing a new concept of Oceanometrics

1964: Dr. Erhard Schimitschek for laser research

1965: Dr. John B. Slaughter for contributions to the field of digital control

1966: Dr. Homer Bucker, Jr., for underwater acoustics research

1967: Richard Pappert for research in VLF and ELF radio waves

1968: Dr. Carroll T. White for development of a human vision diagnostic tool using brainwaves

1969: H.J. Wirth for achievements in satellite communications

1970: Dr. Juergen Richter for work in atmospheric physics

NELC Annual Achievement Awards

1971

Science: Dr. Earl E. Gossard

Engineering: Gary Rogers

Management: Carl W. Erickson

1972

Science: Dr. George Dillard

Engineering: Walter Chase

Management: Richard Eastman

1973

Science: Harry Wieder

Engineering: James Whitaker

Management: Robert Rios

Support: Mary Hower

1974

Science: Dr. Henry F. Taylor

Engineering: C. Vorris Tenney

Management: Ed Shutters

1975

Science: Wesley Eisenman

Engineering: Gary Huckell

Management: John Maynard

Support: Maxine Litten

1976

Science: Sherman Karp

Engineering: Charles Wilhelm

Management: Richard Petty

Support: John Smaldino

NELC Honorary Woman's Award

Established in 1968, the award "will be given annually to that woman who achieves at the Center a high standard of performance in exemplifying the challenging careers for women in Federal Government."

1968: Olive Thompson for twenty-plus years at the lab as a motion picture production specialist

1969: Grace Bostic for direction and leadership of the Center's Personnel program

1970: Robin Dillard for application of mathematical and statistical theory to communications and to the problem of intercepting friendly and unfriendly transmissions of energy

1971: Helen Blanchard for formulation of Fleet Operational Readiness Accuracy Check Site data bank

1972: Nancy Mathis for her development of computer languages

Naval Undersea Center Gilbert H. Curl Award for Science

Named for Dr. Gilbert H. Curl, highly respected ocean scientist and department head at both NEL and NUC.

1971: Dr. Edwin Hamilton for marine geology and sea floor acoustics research

1973: Dr. Sam Ridgway for marine mammal research

1975: Dr. Jack W. Hoyt for hydrodynamics research on drag-reducing polymers

Naval Undersea Center Lauritsen-Bennett Award for Engineering

Named for Dr. Charles Christian Lauritsen, Caltech Physics Department head who was a major force in the establishment of NOTS China Lake and key figure in the Manhattan Project, and RADM Rawson Bennett II, the Commanding Officer and Director of NEL 1946-1950 and later Chief of Naval Research.

1972: Charles G. Beatty for torpedo development

1974: Harper Whitehouse for signal processing

1976: John McCool for signal processing

Military Awards

Military personnel, both officers and enlisted, are assigned to the Center for fairly short periods, on the order of two to four years. Like civilians, they have specific awards, usually characterized as medals, based on their achievements. Often a newly arrived military member will receive a medal almost immediately; that award is based on the individual's performance at a previous command. None of those is listed here. Additionally, for the same reason, we may have missed important awards because they were presented at the individual's next duty station.

Legion of Merit

Lieutenant Don Walsh, February 1960, for his descent to the bottom of the sea in the bathyscaph *Trieste*

Commander Francis R. Walsh, NOTS Air Weapons Officer, March 1967, for his leadership as project officer of Project POPEYE (classified program; all NOTS "eye" projects related to conventional free-fall weapons)

Captain Grady H. Lowe, September 1967, for simultaneous service as Commander, Naval Weapons Center, China Lake and Commander, Naval Undersea Warfare Center, San Diego

Captain/Rear Admiral Mabry D. Van Orden, May 1972, for service as Commander of NELC

Captain Charles B. Bishop, July 1972, for service as Commander of NUC

Captain Robert H. Gautier, July 1975, for service as Commander of NUC

Meritorious Service Medal, July 1975, to retiring NELC Commander Captain N.D. Harding

Navy Commendation Ribbon, February 1960, to Lieutenant Larry Shumaker for his essential role in preparing for the *Trieste* Deep Dive

Navy Commendation Medal, 1969, to Lieutenant Commander Floyd W. Hollister, for work on the Initial Ballistic Correction System for USS *New Jersey* (BB-62), a task he shared with Dr. Robert C. Kolb, for which both received an NELC Achievement Award

Navy Achievement Medal, September 1975, to Chief Gunner's Mate Robert L. Foster, for contributions to a highly classified project at the NUC Hawaii Laboratory

Military Humanitarian Service Award, 1980, to Dr. C. Scott Johnson, for assistance to Navy special forces personnel in clean-up of radiation ravaged Eniwetok Atoll. He was one of the few civilians to receive this military award.

Navy Unit Commendations:

--to NEL's bathyscaph *Trieste* (first ever such award for a research vessel) for location and positive identification of the downed submarine USS *Thresher* (SSN-593), October 1963. Cited personnel included officer-in-charge Lieutenant Commander Donald L. Keach plus ten sailors, and NEL civilians (again unusual) Kenneth V. Mackenzie, Giuseppe Buono, Manuel M. Medina, John R. Houchen, Archie Davis, and John H. Sneed

--in February 1966 for the NOTS military personnel supporting SEALAB II. A select set of those also received the **Rescue Commendation Award** for saving the life of Captain Walter Mazzone when his air supply failed on a deep dive during SEALAB. NEL civilian William Bunton also received the unit award separately, as a member of the SEALAB II dive team, for which he also received the Navy Superior Civilian Service Award.

--for under-ice voyage of USS *Gurnard* (SSN-662) in November 1976 to NELC's Dr. Waldo Lyon, Richard J. Boyle, and Terry R. Luallin

Meritorious Unit Commendations:

--to USS *Elk River* (IX-501) in January 1974, for supporting operation of the Mark II Deep Dive System

--in October 1976 for the Mediterranean ASW Augmentation Program, which included a number of NUC civilians

Navy Awards of Merit for Group Achievement

This award is presented to groups (civilian and military) for outstanding service in connection with a single project, program, or other effort of substantial benefit to the mission of the Navy.

--CURV III, November 1971, for work on the Azores Fixed Acoustic Range

--USS *Dolphin*, November 1971, for development work on a new sonar system

--CURV III, May 1974, for rescue of the stranded submersible *Pisces* III

--US/UK Sonar System, January 1975

--AN/SQR-15 Towed Array Sensor System, February 1975

--Third Fleet Active/Passive acoustics project, April 1975

--Towed Array Sensor System Test Bed project, November 1975

--Mark 116 Underwater Fire Control System, November 1975

--Design, fabrication of Hydraulic Torpedo Tube Launcher, November 1976

--SUBICEX 1-76, USS *Gurnard* (SSN-662), February 1977

Major monetary awards

Federal Government Incentive Award of $25,000, “the highest monetary award ever made by the Government in recognition of an employee’s superior accomplishment,” to Dr. William B. McLean in 1956 for development of the Sidewinder missile

Patent award of $11,235 to Dr. Carroll T. White and Dr. Russell M. Harter in 1975 for their joint development of a vision testing method based on brain reactions to a flashing checkerboard pattern, measuring evoked response determined by a computer

Incentive award of $4,700 (largest ever presented to a Bureau of Ships employee) to NEL’s Paul Fiske in 1960 for development of an electronic guidance system

Other Awards

Polaris flag presented to Pasadena Annex of NOTS in April 1964 for major support in submarine-launched missile development

Poseidon flag to NUC in February 1972 for significant involvement in fielding of Poseidon missiles to fleet ballistic missile submarines

Presidential Management Improvement Award to NUC's Meyer Lepor, for cost savings associated with equally effective but substantially less costly acoustic barriers for USS *Los Angeles* (SSN-688) class submarines, August 1975. He had previously (1974) received a **Secretary of the Navy Cost Reduction Award** for the project.

Presidential Citation for economy achievement to NEL's Charles Green for design and construction of the Transducer Evaluation Center, January 1965

Secretary of the Navy Environmental Protection Award (first) to NUC for environmental survey of Pearl Harbor, 1972

Secretary of the Navy Management Improvement Award to NUC's Jim Gilbreath for leadership in increasing the capabilities of Navy USQ-20 shipboard computers, 1974

Secretary of the Navy Certification of Commendation to NEL's E.B. Robinson for service as a member of Polaris Missile Steering Task Group Command Communications Committee, 1961

Secretary of the Navy Certification of Commendation to NEL's Dr. Don Wilson for service as member of the Polaris Ad Hoc Group for Long Range R&D, May 1966

Secretary of the Navy Safety Awards to NOTS China Lake in 1956 for Industrial Safety and Motor Vehicle Safety, and to NEL for Safety Ashore in 1971

Special Projects Office Award of Merit to the NOTS Pasadena Annex for Polaris missile support, including testing at San Clemente Island

Military Oceanography Award, 1969, to NUC's Ed Carpenter for his support of SEALAB III and Dr. Eugene LaFond for his studies of near-shore oceanographic processes

Miss Federal Secretary—Julia Kinnard, representing the NOTS Pasadena Annex in a Los Angeles-wide competition, December 1955

Miss Federal Employee for 1960—Dr. Catherine Campbell, selected from the 27,600 women federal employees of southern California, February 1960

Professional Society Awards

Acoustical Society of America Distinguished Service Citation to Dr. Robert W. Young (UCDWR, NEL, NUC), November 1973

American Association of Petroleum Geologists Francis P. Shepard Award for Excellence in Marine Geology (first) to Dr. David G. Moore of NEL, April 1967

American Cetacean Society Man of the Year to Steve Leatherwood of NUC, August 1973

American Ordnance Association Blandy Gold Medal to Dr. William B. McLean, 1960

American Society of Mechanical Engineers Freeman Scholarship (first) to Dr. J.W. Hoyt, 1971

American Society of Naval Engineers Gold Medal for 1958 to Valor Smith, head of the NEL Ship Antenna Section

American Society of Naval Engineers Gold Medal for 1959 to NEL's Dr. Waldo Lyon for his Arctic explorations

American Society of Naval Engineers Solberg Award to NELC's Dr. Henry Taylor for his work in integrated optics technology and fiber optics communication for naval applications, 1975

Institute of Electrical and Electronic Engineers Harry Diamond Award to Dr. William B. McLean, 1972

Instititute of Electrical and Electronic Engineers Council on Oceanic Engineering Outstanding Technical Achievement Award to Dr. Howard A. Wilcox, 1975

Institute of Navigation 1970 Superior Achievement Award to Kenneth V. Mackenzie

Junior Chamber of Commerce Arthur H. Flemming Award to Douglas J. Wilcox, 1959

Marine Technology Society Lockheed Award for Ocean Science and Engineering to Dr. Tom Lang for design and development of the Stable Semi-submerged Platform, 1976

Marine Technology Society Special Commendation in 1974 for the CURV III role in rescue of *Pisces III* crew

Philadelphia Academy of Natural Sciences Richard Hopper Day Medal (first recipients) to the crew of the *Trieste* in 1960, Lt. Don Walsh and Jacques Piccard

Rockefeller Public Service Award for Science, Technology, and Engineering to Dr. William B. McLean, 1965

Theodore Roosevelt Association Gold Medal to Lt. Don Walsh and Jacques Piccard in 1960 for Trieste Deep Dive. Previous naval officer recipients of the award were Admiral Chester W. Nimitz, Admiral William F. Halsey, and Vice Admiral Hyman Rickover.

C: Leadership

An organization's leaders—inspired, mediocre, failed—play a critical, if not essential, role in the success or failure of that organization. Through the course of an eight-decade history, Naval Information Warfare Center Pacific and its many predecessor organizations have been blessed with a substantial majority of good to great leaders. The general model of both a senior military officer and a senior technical civilian in dual leadership roles contributed to that excellence. These are the individuals who filled those roles for the first half of Center history.

U.S. Navy Radio and Sound Laboratory (Commanding Officer and Director)

Commander J.B. Dow	1940 (5 months)
Captain W.J. Ruble	1940-1942
Captain P.H. Hammond	1942-1945

NRSL/U.S. Navy Electronics Laboratory (Commanding Officer and Director)

Captain Paul Hord	1945-1946

NEL (Commanding Officer and Director)

Captain Rawson Bennett	1946-1950
Captain D.P. Tucker	1950-1953
Captain H.E. Bernstein	1953-1956
Captain G. Hunter	1956

Captain J.M. Phelps	1956-1960
Captain J.H. Allen (Acting)	1960
Captain Frank B. Herold	1960-1962
Captain Harry C. Mason	1962-1965

NEL/Naval Command Control Communications Laboratory Center/Naval Electronics Laboratory Center (Commanding Officer and Director/Commander)

Captain William R. Boehm	1965-1969

NELC (Commander)

Captain Mabry D. Van Orden	1969-1972*
Captain Norton D. Harding, Jr.	1972-1975
Captain Robert R. Gavazzi	1975-1977

* Selected for flag rank during his tour at the Center

NEL (Superintending Scientist)

Dr. J.P. Maxfield	1948-1953

NEL (Technical Director)

Dr. F.N.D. Kurie	1953-1960

NEL/NCCCLC/NELC (Technical Director)

Dr. Ralph Christensen	1960-1969

NELC (Technical Director)

Dr. Clarence E. Bergman	1969-1977

U.S. Naval Ordnance Test Station (Commanding Officer)

Captain Sherman E. Burroughs	1943-1945
Captain James B. Sykes	1945-1947

NOTS (Commander)

Rear Admiral Wendell G. Switzer	1947-1949
Captain Walter V.R. Vieweg	1949-1952
Captain Paul D. Stroop	1952-1953*
Captain Robert H. Solier	1953 (2 months)
Captain David Young	1953-1955
Captain Robert F. Sellars	1955 (2 months)
Captain Frederick L. Ashworth	1955-1957
Captain William W. Hollister	1957-1961
Captain Charles Blenman, Jr.	1961-1964
Captain Leon Grabowsky	1964 (2 months)
Captain John I. Hardy	1964-1967
Captain Grady H. Lowe	1967+

* Selected for flag rank during his tour at the station
+ Dual-hatted as Commander, NWC China Lake and NUWC Pasadena

NOTS (Technical Director)

Dr. L.T.E. Thompson	1945-1951
Dr. Frederick W. Brown	1951-1954
Dr. William B. McLean	1954-1967

Naval Undersea Warfare Center (Commander)

Captain Grady H. Lowe	1967-1969

NUWC/Naval Undersea Research and Development Center/Naval Undersea Center (Commander)

Captain Charles B. Bishop	1969-1972

NUC (Commander)

Commander William J. Gunn	1972
Captain Robert H. Gautier	1972-1975
Captain R. Bruce Gilchrist	1975-1977

NUWC/NURDC/NUC (Technical Director)

Dr. William B. McLean	1968-1974

NUC (Technical Director)

Dr. Howard L. Blood	1974-1977

Naval Ocean Systems Center (Commander)

Captain Robert R. Gavazzi	1977

NOSC (Technical Director)

Dr. Howard L. Blood	1977

D: *La Playa*

(*La Playa* are the Spanish words for “the beach” or “the shore.” It was the term applied to the general area on the eastern shore of Point Loma where San Diego’s first port operated. Along the beaches bordering the harbor here, a number of structures and piers for widely varying purposes have been constructed in the nearly five centuries since Cabrillo landed at Ballast Point. Although those structures and purposes are not all directly contributory to this project, some of those structures remain and do constitute at least a peripheral part of this history.)

The waterfront area occupied for eight decades by the Navy laboratory on Point Loma, officially termed for more than half of those decades “Bayside,” was a perfect location for a wide variety of uses requiring a calm harbor with gently sloping beaches a short distance from relatively deep water. Those qualities allowed fair-sized ships (and, after concentrated dredging, even the U.S. Navy’s “super” aircraft carriers of 100,000 tons displacement) to shelter from the open waters of the Pacific Ocean and discharge cargoes of all sizes and shapes and descriptions. Of the myriad ships which have sailed and steamed into that harbor for nearly half a millennium, also of all sizes and shapes and descriptions, the first were three Spanish ships arriving on September 30, 1542, under the command of Juan Rodriguez Cabrillo. At the time, Cabrillo named the bay San Miguel, calling it a “closed and very good port.” It is believed Cabrillo came ashore at what later became known as Ballast Point, claiming the harbor, the rugged peninsula to the west, and the surrounding area for Spain.

At a point almost directly overhead of Cabrillo’s landing party, four hundred feet above sea level, the federal government of a country that did not exist at the time would honor his arrival with an important landmark. A quarter of a century after establishment of what became Cabrillo National Monument, the Secretary of the Navy of that country would commission, a few miles north, a research and engineering organization that is today Naval Information Warfare Center Pacific.

A lot would happen on and in the near vicinity of that stretch of gently sloping beaches in the centuries following Cabrillo’s discovery: somewhat critically, Sebastian Vizcaino arrived November 10, 1602, pursuing his duties to locate safe harbors for Spanish galleons sailing between the Philippines and Acapulco. Taking a hint from his flagship, the *San Diego*, he renamed the bay in its honor.[1]

(Some distance inland from and east of that bay, a fort would be built; missionaries would arrive; the Mexicans would drive out the Spanish; the Americans would drive out the Mexicans [twice]; the American state of California would replace the Mexican province of Alta California; a settlement would grow and become a town and eventually a city.)

On *La Playa*, the period of the mid-1800s saw the arrival of whaling ships, establishing a several-decade intermittent presence near Cabrillo's landing spot at Ballast Point. Already in place slightly farther north was another major commercial enterprise, one initiated in 1822 and based on the huge Mexican land-grant *ranchos* up the coast. Vast herds of livestock roamed those coastal areas, raised for beef and for their hides.[2] American merchant ships from East Coast ports, principally Boston, sailed up and down the coast, collecting fresh hides and transporting them to San Diego.

"We were always glad to see San Diego; it being the depot, and a snug little place, and seeming quite like home, especially to me, who had spent a summer here," wrote Richard Henry Dana.[3] A Harvard undergraduate whose eyesight had been severely impaired by a case of measles, Dana had taken the extreme remedial measure of signing up as a common seaman on the *Pilgrim*. The ship sailed from Boston around Cape Horn to California in 1834. In spare moments between the harried and brutal life of a seaman, Dana kept a daily journal, from which notes he would write his chronicle, intended to improve the lives of his fellow sailors, when he returned to Boston.

Sailing from the north along the coast one day, he recorded his impressions of

---

[1] Iris Wilson Engstrand, *San Diego: California's Cornerstone,* Sunbelt Publications, Inc., 2005, 80.

[2] According to an article in the June 4, 1976 Naval Undersea Center *Seascope*, Bostonian William A. Gale, an early visitor to the area, had seen the cattle ranches that year (1822) and imagined the commercial possibility of cow hides in the Eastern marketplace. He arranged for a batch of hides to be loaded aboard the ship of which he was the commercial officer; the financial success of his efforts stimulated the sailing of a number of Atlantic coast ships on the long and hazardous voyage around Cape Horn to California and back with hides.

[3] *Two Years Before the Mast*. New York: Penguin Books, 1964, 60.

the surrounding area:

> At sunset on the second day [sailing from San Pedro] we had a large and well-wooded headland before us, behind which lay the little harbor of San Diego… the little harbor, which is rather the outlet of a small river… A chain of high hills [Point Loma], beginning at the point (which was on our larboard hand coming in) protected the harbor on the north and west, and ran off into the interior, as far as the eye could reach… There was no town in sight, but on the smooth sand beach, abreast, and within a cable's length of which three vessels lay moored, were four large houses, built of rough boards, … with piles of hides standing round them… These were the hide houses…[4]

Dana describes in great detail the collection of fresh hides and the laborious task of bringing them aboard for the sail to San Diego; the processes of curing, drying, and storing them in the hide houses while the ship sailed north for more; *La Playa,* where those processes took place; and finally the complex operation of loading them for the return voyage to Boston. He is effusive in his praise of the location:

> For landing and taking on board hides, San Diego is decidedly the best place in California. The harbor is small and landlocked; there is no surf; the vessels lie within a cable's length of the beach, and the beach itself is smooth, hard sand, without rocks or stones. For these reasons, it is used by all the vessels in the trade as a depot; and, indeed, it would be impossible, when loading with the cured hides for the passage home, to take them on board at any of the open ports, without getting them wet in the surf, which would ruin them.[5]

(Dana sailed home on the *Alert* after surviving a trying encounter that threatened to extend his time on the West Coast by another year, arriving back in Boston in September 1836.)

Chapter 14 relates the story of two of Dana's "predecessors," sailors from a ship collecting hides half a dozen years before he arrived on *Pilgrim*. (And it is an interesting possibility Dana had read the article in the Boston *Sun* reporting their story, which might have stimulated his interest in sailing to California.) Very briefly, the pair fashioned a U.S. flag from various red, white, and blue articles of clothing and waved it to attract attention from the occasional ship entering San Diego harbor and thus have some company in what was a fairly lonely existence.

Ten years after the merchant ship *Alert* sailed out of San Diego harbor with a full load of hides and Richard Henry Dana aboard, the military sloop USS *Cyane* sailed in and anchored off Ballast Point, claiming the port and surrounding area for

---

[4] *Two Years Before the Mast*, 105.
[5] *Two Years Before the Mast*, 116.

the U.S. (The Ballast Point-*La Playa* area would serve as San Diego's port until the 1870s, when the civic center moved from Old Town to its present location and permanent piers were erected along what is today Harbor Drive.) Appropriate members of the crew made their way to the plaza of the "Old Town," and there, at 4:00 p.m. on July 29, 1846, the U.S. flag was raised officially in California for the first time.

Six years later, on February 26, 1852, President Millard Fillmore signed an executive order establishing a military reservation of 1,300 acres on the Point Loma peninsula. It would be almost two decades before the U.S. Army took charge of the area, evicting the whaling companies that had used the area as a shore station during the whaling season.[6]

The Army took possession of the military reservation "and nearby Ballast Point in 1870… but it was not occupied until February 1898… and named Fort Rosecrans by general order on 22 July, 1899."[7] According to author Bart Everett, a few weeks before that general order, construction was completed on the first coastal defense battery, Wilkeson (which was split into Wilkeson and Calef in 1915 and reunited as Calef-Wilkeson in 1919); the "reinforced-concrete structure was armed with four 10-inch rifles on M1896 disappearing carriages."[8]

Marine Hospital Service

Half a dozen years before the Coast Artillery unit arrived in 1901 to man Battery Wilkeson, another federal entity had come to *La Playa*: the Marine Hospital Service. Tracing its origins nearly to the founding of the republic, the

---

[6] California gray whales (*Eschrichtius robustus*) pass Point Loma by the thousands each year beginning in December, heading for their winter mating/calving grounds in bays off Baja California. Most famous of these is *Laguna Ojo de Liebre*, previously called Scammon's Lagoon after a whale-hunting captain of the mid-1800s. The whales arrive in late December and January, spend February and early March here, and depart in March and April, heading back to their summer feeding grounds in the Arctic. The 10,000- to 12,000-mile round trip is one of the longest migration journeys in nature. For decades, boats have departed Point Loma filled with people armed not with harpoons but with still and video cameras to record this phenomenon. Their whale "take" is dozens of photos.

[7] H.R. Everett, *WWII Harbor Defenses of San Diego*, Introduction, Coast Defense Study Group Press, McLean, Va., 2021, 2.

[8] Everett, 13.

service originated with individual, locally administered marine hospitals authorized by "An Act for the Relief of Sick and Disabled Seamen," passed by the fifth U.S. Congress in1798. Beginning with a facility in Boston, individual marine hospitals were established at other East Coast ports, providing a safety net for ill sailors.

In the 1830s and 1840s, hospitals were constructed on inland waterways, the Great Lakes, and the Gulf of Mexico, expanding to West Coast ports as Oregon and California became part of the U.S. In 1870, the loose association of individual hospitals was formalized into the Marine Hospital Service, headquartered in Washington, D.C. The service operated under the Coast Guard forerunner Revenue Marine Service, assigned to the Department of the Treasury.

The service expanded the number of its facilities, and gradually assumed a previous individual state responsibility to quarantine individuals, both seamen and ship passengers, who upon arrival in port presented with symptoms of infectious diseases. Beginning in 1891, the federal government took control of immigrant processing from the individual states, and under its authority the Marine Hospital Service began managing such sites as Ellis Island. Commissioned officers assigned to the service administered the immigration process and in doing so managed responsibility as well for preventing disease from entering the country.

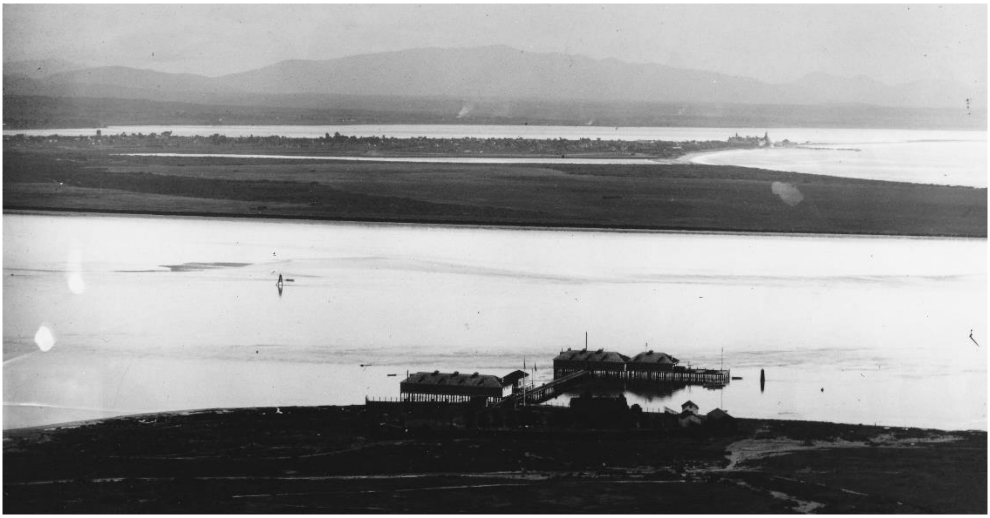
On the West Coast, the port of San Diego was one of those included in that responsibility. In 1893, the service established a quarantine station on several piers extending into San Diego harbor from *La Playa*. Four buildings were constructed to pursue that effort, three of them on the piers. The fourth, designated the Attendants' Quarters, was just inland from that beach where, half a century earlier, Richard Henry Dana and his companions had transferred cattle hides between ships and hide houses. In 1995, a formal evaluation report on the structure, which is now the Naval Information Warfare Center Pacific Dolphin Facility, stated:

> Building 190 is the sole survivor among the four buildings that made up the original station. The building served its original function until 1944, when the Quarantine Station was absorbed by the United States Navy as part of the nation's mobilization for World War II.[9]

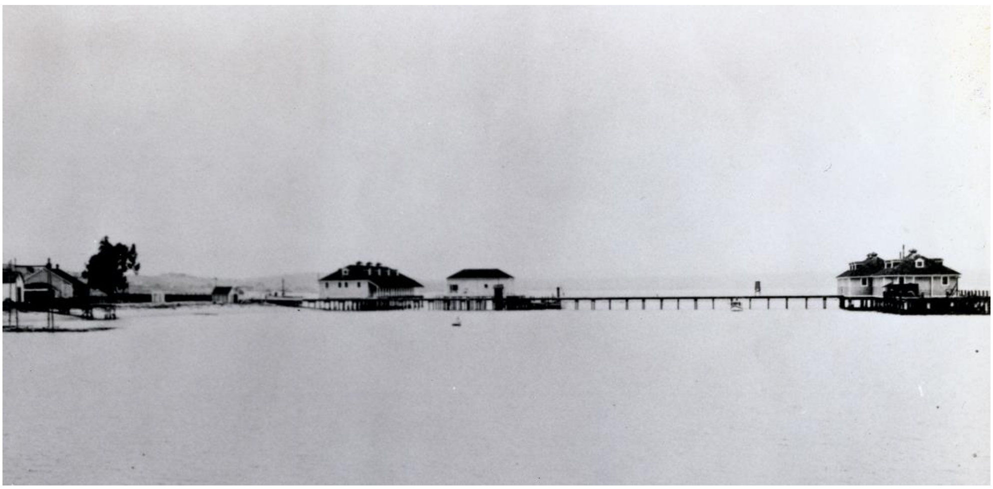
Interestingly, the Navy had been trying to do that ("absorb" the quarantine station) for four decades, although the service admittedly had shown little interest in San Diego (or in any southern California port, for that matter) in the eighteenth

[9] Ferris, Johnson & Perkins, Architects, Inc., "Historic Structure Report: Attendants' Quarters of the San Diego Quarantine Station (1893-1944)," February 1995, 1.

century. This was true despite the fact the geography of Point Loma and what is today North Island, plus the construction of Zuniga Shoals jetty extending to the



Two early photos (1905) of the Quarantine Station. Top photo shows the site, directly across the harbor, where Naval Air Station North Island (called originally NAS San Diego) would be built in a dozen years. Beyond that is Coronado and, in the far distant moutains, Mexico. In both photos, most of the station buildings are actually on the pier.



south from North Island, provided an excellent harbor accessible to large ships.

Unfortunately, the city itself, aptly described in Engstrand's book above ("cornerstone"), had limited access by land to and from the east (desert), the south (a foreign country), and the west (the Pacific Ocean). And for all practical purposes its nearby neighbor to the north—Los Angeles—essentially completed its isolation. That isolation substantially limited its attractiveness to shipping, transportation, and business interests. Seeking to remedy that, the Chamber of Commerce considered the U.S. Navy a potential target to stimulate growth.

Initial efforts beginning in 1893, including proposals for a hydrographic office and a ship repair facility, gained little traction. A major proposal in 1900 offered a much better possibility: a coaling station for Navy ships. The nearest one at the time was five hundred miles to the north, in San Francisco Bay.

The chamber began a major letter-writing and personal-visit campaign to focus Navy interest on the coaling station. With a little seed money from Congress for a site survey and the interest of the acting Secretary of the Navy, a Navy ship, USS *Ranger*, was ordered to San Diego, its captain tasked with determining the most favorable placement for the station, reasonably somewhere on *La Playa*.

In response, the captain reported his finding, characterized by a historian as

> a 'bayside beach' that featured a gently sloping shoreline that could support buildings and offered ample storage space, a shallow inshore that was perfect for constructing a pier, and enough contiguous deep water to allow vessels to safely approach.[10]

The significant problem was that "bayside beach" was occupied by the U.S. Treasury Department's quarantine station! *Ranger*'s captain and the Treasury Department's surveyor had no doubt employed similar if not identical criteria in selecting the site for their respective stations, and what had appeared as an easy win for the San Diego Chamber of Commerce in inviting the Navy to town turned into a decade-long battle between two major U.S. Government departments.

High-ranking officials of both departments visited San Diego during the early years of the twentieth century, coming away convinced the only possible site for their station was that single parcel of land. Amid a flurry of letters between and among various officials and agencies, the California congressional delegation introduced a number of bills pushing for "the establishment of the coaling station

---

[10] John Martin, "The San Diego Chamber of Commerce Establishes the U.S. Navy Coal Station, 1900-1912," *Journal of San Diego History*, 219.

on ‘Blocks 93 and 94 of the La Playa,’ which the quarantine station occupied.”[11]

In September 1901, the War Department transferred ownership of 2,900 feet of its military reservation shoreline, immediately south of the quarantine station, to the Navy Department for the proposed coaling station. Despite that, the Navy continued to maintain the specific area occupied by the quarantine station was essential to its needs, and the city chamber of commerce waved the flag of “national defense” at the Treasury Department, which persisted in its belief, based on a visit of one of *its* officials, that its station needed to remain where it was.

Since it was sold on the general concept of a San Diego/Point Loma coaling station, the Navy proceeded to authorize funds and initiate construction on the station in the area transferred by the War Department. A steel pier was built, as was an approach pier, two towers for loading coal, and a storage area for 25,000 tons of coal. Although the Navy continued its futile efforts to acquire the land occupied by the quarantine station, it established its first command in San Diego, the Navy Coaling Station, in 1904. (As a probable low point in the San Diego/Navy relationship, the naval event of the decade, or several—the arrival of Roosevelt’s Great White Fleet in 1908—found the coaling station fully operational but the harbor approaches insufficiently dredged to allow the fleet to enter; the mighty armada of ships had to anchor off Coronado rather than steaming majestically into the harbor.)

Subsequent history

In 1933, the San Diego Historical Society commemorated the unofficial first raising of the American flag in the “shirt-tail flag” incident (see Chapter 14) by planting a eucalyptus tree on the site of the hide house where the incident occurred. In 1934, the Girl Scouts placed a marker memorializing that event, near the quarantine station’s first building on land, the attendants’ quarters.

Over the years, as Navy ship propulsion modernized, the coaling station became the refueling pier. As mentioned earlier, in 1944 the quarantine station and the marine hospital were relocated, and the area was transferred to the Navy. On August 4, 1947, the Navy transferred more than ten acres of the Navy Fuel Facility

[11] John Martin, 223.

and Small Craft Facility to the U.S. Navy Electronics Laboratory for a designated waterfront area for its small craft and submarines to support sonar and ASW efforts. Two years later, on June 30, 1949, the Navy finally managed to gain those "Blocks 93 and 94 of the La Playa," when the property of the quarantine station was transferred from the Public Health Service to NEL.

Dave Willis, a Vietnam War veteran, returned home to San Diego in 1973 and secured a job as a carpenter with the Navy Public Works Center. His "absolute first task was to repair some windows" in Building 190, previously the quarantine station attendants' quarters.[12] Thirty-seven years later, after a career that included heading the Point Loma lab's facilities office, his retirement party was held in that building. With personal enthusiasm above and beyond official duties, he had overseen conversion of Building 190 to the lab's recreation facility, the Dolphin Club, based on a nearby pier where Navy dolphins resided in enclosures in the bay.

On April 3, 1989, the commander of the laboratory (at the time the Naval Ocean Systems Center), Captain Earl Schweizer, joined members of the San Diego Historical Society and Squibob Chapter 1853 in dedicating and rededicating monuments to the *La Playa* era on Rosecrans Street at the entrance to NOSC Bayside and the Naval Submarine Base.[13] The original marker commemorated Cabrillo's discovery of the area and was initially placed at the end of the *La Playa* Trail in 1934. Dedicated on this date (1989) was a new marker for California Registered Historical Marker No. 61 "for old La Playa, the port of San Diego from 1770 until 1870… At that time, La Playa was a thriving trading and shipping village." The *La Playa* Trail, memorialized in one of the markers, ran from the Point Loma port to Old Town, the city's center in those days. Old as it was, it followed a Native American commercial trail hundreds of years older, and thus the marker calls it "one of the oldest commercial routes in the far West."

As mentioned above, in 1994 the Point Loma Navy lab contracted with an architectural firm to evaluate the attendants' quarters/Dolphin Facility. According to Dave Willis:

> It was after the renovation that our office submitted a request to have the quarantine station buildings still standing, including the Dolphin Facility building, be declared historical buildings in the federal registry… At the outcome, building 190 was approved and put into the registry.[14]

---

[12] Dave Willis email to Tom LaPuzza, February 8, 2019.

[13] "NOSC, Squibob dedicate historical markers Apr. 3," NOSC *Outlook*, April 14, 1989, 4.

[14] Dave Willis email.

Sources

Books

Au, Whitlow W.L. *The Sonar of Dolphins*. NY: Springer-Verlag, 1993

Babcock, Elizabeth. *History of the Navy at China Lake, California, Volume 3: Magnificent Mavericks.* Washington, D.C.: Naval History Center/Naval Air Systems Command, 2008

Boslaugh, David L. *When Computers Went to Sea: The Digitization of the U.S. Navy*. Los Alamitos, California: The Institute of Electrical and Electronic Engineers, Inc., 1999

Bush, Vannevar. *Pieces of the Action*. N.Y.: Morrow, 1970

Christman, Albert B. *History of the Naval Weapons Center, China Lake, California, Volume 1: Sailors, Scientists, and Rockets.* Washington, D.C.: Naval History Division, Government Printing Office, 1971

Craven, John Pina. *The Silent War*. NY: Simon and Schuster, 2001

Forman, Will. *The History of American Deep Submersible Operations, 1775-1995*. Flagstaff: Best Publishing Co., 1999

Gannon, Robert. *Hellions of the Deep*. University Park, Pennsylvania: The Penn State University Press, 1996

Gebhard, Louis A. *Evolution of Naval Radio-Electronics and Contributions of the Naval Research Laboratory* (Washington, D.C.: Naval Research Laboratory, 1979).

Gerrard-Gough, J.D., and Albert B. Christman. *History of the Naval Weapons Center, China Lake, California, Volume 2: The Grand Experiment at Inyokern.* Washington, D.C.: Naval History Division, Government Printing Office, 1978

Howeth, Captain L.S., USN (Ret.). *History of Communications-Electronics in the United States Navy.* Washington, D.C.: U.S. Government Printing Office, 1963

Lawson, Cliff. *History of the Navy at China Lake California, Volume 4: The Station Comes of Age.* China Lake, California: United States Navy Naval Air Warfare Center Weapons Division, 2017

Leary, William M. *Under Ice.* College Station, Texas: Texas A&M University Press, 1999

Piccard, Jacques and Robert S. Dietz, *Seven Miles Down*. New York: G.P. Putnam's Sons, 1961

Ridgway, Sam. *The Dolphin Doctor*. New York, Fawcett Crest, 1987

Sapolsky, Harvey M. *The Polaris System Development*. Cambridge, Massachusetts: Harvard University Press, 1972

Stachiw, J.D. *NOSC: Ocean Engineering Studies* (11 volumes). San Diego: Naval Ocean Systems Center, 1990

Talkington, Howard R. *Undersea Work Systems*, Ocean Engineering Series 1. NY: Marcel Dekker, Inc., 1981

U.S. Navy. *Chronological History of U.S. Naval Communications*. 1958.

University of California Division of War Research. *Completion Report*. San Diego: 30 June 1946

Urick, Robert J. *Principles of Underwater Sound for Engineers*. New York: McGraw Hill, 1967

Waugh, John G. and G. W. Stubstad, *Hydroballistics Modeling*. San Diego: Naval Undersea Research and Development Center, 1972

Wood, Forrest G. *Marine Mammals and Man: The Navy's Porpoises and Sea Lions* Washington-New York: Robert B. Luce, Inc., 1973

Articles

Allison, David K. "U.S. Navy Research and Development since World War II." In: Merritt Roe Smith, Editor. *Military Enterprise and Technological Change: Perspectives on the American Experience.* Cambridge, Massachusetts: The MIT Press, 1985

Chastain, Lieutenant Commander John A., U.S. Navy. "The Role of Computers in Combat Control," USNI *Proceedings* (September 1961)

Dietz, Robert S. "Continent and Ocean Basin Evolution by Spreading of the Sea Floor," *Nature* 190 (June 3, 1961):854

Evans, Bryant. "Electronic 'Brain' Bared By NEL For Combat Use," San Diego *Union* August 27, 1960, 1

Gates, Robert V. "History of the Navy Laboratory System," *International Journal of Naval History* April 2016

Gaul, Dr. Roy D., "LRAPP Exercises Revisited," 26 June 2003

Hammond, Captain P.H., USN (Ret.), "The U.S. Navy Radio and Sound Laboratory," *Journal of Applied Physics* 15 (March 1944): 240-242

LaPuzza, Tom. "Information Dominance," *Mains'l Haul* 48: 3 & 4 (Summer/Fall 2012): 46-59

LaPuzza, Tom. "San Diego-based Research Submarines," *Mains'l Haul* 50: 3 & 4 (Summer/Fall 2014): 66-73

LaPuzza, Tom. “Small San Diego Lab Makes a Big Difference,” *Mains’l Haul* 50: 3 & 4 (Summer/Fall 2014): 54-65

Lyon, W.K. “Submarine Combat in the Ice,” U.S. Naval Institute *Proceedings* 118 (2), (1992): 38

Martin, Lieutenant George W. “Trieste: The First Ten Years,” U.S. Naval Institute *Proceedings* 90, No. 8 (August 1964): 58-60

McLean, William B. “A Bedrock View of Ocean Engineering,” *Astronautics and Aeronautics*, April 1969: 32

Munk, Walter and Deborah Day. “Harald U. Sverdrup and the War Years,” *Oceanography* 15, No. 4, 2002

Paolucci, Captain Dominic A., USN (Ret.). “The Development of Navy Strategic Offensive and Defensive Systems,” U.S. Naval Institute *Proceedings* (May 1970): 204-23

Pierce, J.A. “Omega,” *IEEE Transactions on Aerospace and Electronic Systems* (December 1965): 200-215

Riley, John. “The Navy’s Top Handyman,” *Life* (6 January 1967): 31-35

Snyder, Conway W. “Caltech’s *Other* Rocket Project: Personal Recollections,” *Engineering and Science*, Spring 1991

Speiss, Fred and William Kuperman, “The Marine Physical Laboratory at Scripps,” *Oceanography* 6, No. 3, 2003

Talkington, Howard R. “NOTS, San Clemente Island,” U.S. Naval Institute *Proceedings* (June 1960): 93

Talkington, Howard R. “The U.S. Navy Participation in the Rescue of the Pisces III,” *Marine Technology Society Journal* 8:1, January 1974

Welty, Howard O. “S.D. Becomes Research Center for Electronics,” San Diego *Union* September 29, 1946

Whitman, Edward C. “SOSUS—The ‘Secret Weapon’ of Undersea Surveillance,” *Undersea Warfare* 7: 2 (Winter 2005)

Worley, Robin A. “Optimum Thresholds for Binary Integration,” *IEEE Transactions on Information Theory,* March 1968

Proceedings

Acoustical Society of America. *Proceedings of Meetings on Acoustics,* Pittsburgh, Pennsylvania, 18-22 May 2015 (special session meeting dedicated to the seminal early efforts in ASW)

Presenters and their topics

Knobles, D.K.; Evan K. Westwood; and Thomas G. Muir. “Columbia University Division of War Research and the work of Ewing, Worzel, and Pekeris”

Kuperman, William A. “The University of California Division of War Research and the Marine Physical Laboratory”

Pestorius, Frederick M. and David T. Blackstock: “Contributions to the development of underwater acoustics at the Harvard Underwater Sound Laboratory (HUSL)”

Center Publications

Hammond, Captain P.H., “U.S. Navy Radio and Sound Laboratory Quarterly Report,” September 1945

Johnson, C.S., “Auditory Thresholds of the Bottlenosed Porpoise (*Tursiops truncatus* Montagu),” U.S. Naval Ordnance Test Station Report 4178, 1966

LaPuzza, Tom, “SSC Pacific celebrates 70 years on the Point,” SSC Pacific *News Bulletin* June 2010

Lyon, W.K., “NEL Submarine Research Facility.” U.S. Navy Electronics Laboratory Research Report 88, 18 November 1948, reissued 21 May 1959

Naval Ocean Systems Center, *Fifty Years of Research and Development on Point Loma, 1940-1990,* Technical Document 1940, 1990

Naval Undersea Research and Development Center, *Ocean Engineering*, NURDC Technical Publication 278, January 1972

Rechnitzer, A.B., “Summary of the Bathyscaph Trieste Research Program Results (1958-1960),” NEL Report 1095, 2 April 1962

Space and Naval Warfare Systems Center Pacific, SSC Pacific 75th Anniversary *News Bulletin* Special Edition-2015

Space and Naval Warfare Systems Center San Diego, *Annotated Bibliography of the U.S. Navy Marine Mammal Program*, Technical Document 627, Rev. D, May 1998

Stephenson, R.G., Coordinator, “LORAD Summary Report,” NEL Report 698, 22 June 1956

Talkington, Howard R., “Why Man?” Naval Undersea Center Technical Note 953, February 1973

U.S. Navy Electronics Laboratory, “Proposed Acoustic and Oceanographic Program for the Deep-Diving Submarine *Dolphin* (AGSS-555),” NEL Technical Memorandum 583, 14 January 1963

U.S. Navy Electronics Laboratory *Station Journal 1940-1967*

Waldie, R.L. “Proposed Sonar Suit and Research Program for the Deep-Diving Submarine *Dolphin* (AGSS-555),” Navy Electronics Laboratory Letter Report 081, January 1963

Wells, W.B. USNEL Report No. 1, “Ship Antenna Systems Model Range—Instrumentations & Techniques,” 28 March 1947

Oral Histories

Morris Akers. Interview by Tom LaPuzza, February 7, 2013
Captain Charles B. Bishop, USN (Ret.). Interview by Dr. Mark Jacobsen, October 1987
Ron Broersma. Interview by Tom LaPuzza, May 27, 2016
Norm Estabrook. Interview by Tom LaPuzza, January 5, 2012
Jim Gilbreath. Interview by Tom LaPuzza, November 28, 2017
Dr. Frank Gordon. Interview by Tom LaPuzza, June 28, 2012
Jeff Grossman. Interview by Tom LaPuzza, August 2, 2012
Mort Heinrich. Interview by Tom LaPuzza, June 20, 2012
Robert M. Hillyer. Interview by Tom LaPuzza, August 21, 2013
Dr. John Hood. Interview by Tom LaPuzza, June 14, 2012
Barbara Houlton. Interview by Tom LaPuzza, June 19, 2018
James H. Jennison. Interview by J.D. Gerrard-Gough, October 23, 1975
Dr. Robert Kolb. Interview by Tom LaPuzza, October 18, 2012
Dr. Waldo Lyon. Interviews by Commander Etta Belle Kitchen, USN (Ret.), 1972
Don Moore. Interview by Elizabeth Babcock, October 11, 1990
Ralph Myers. Interview by Dan Cisco and Tom LaPuzza, March 3, 2020
Bill Powell. Interview by Tom LaPuzza, September 13, 2012
Dr. Juergen Richter. Interview by Tom LaPuzza, September 11, 2012
Dr. Sam Ridgway. Interviews by Tom LaPuzza, June 27 & August 8, 2012
Paul Singer. Interview by Tom LaPuzza, November 8, 2012
Dr. John Slaughter. Interview by Tom LaPuzza, January 21, 2020
Alvah T. Strickland. Interview by Tom LaPuzza, June 5, 2012
Augie Troncale. Interview by Tom LaPuzza, July 12, 2012
Dr. Ed Tunstall. Interview by Tom LaPuzza, May 2, 2019
Stan Vermeers. Interview by Tom LaPuzza, July 26, 2012
Bob Watts. Interviews by Tom LaPuzza, December 20, 2011 & September 20, 2012

Frank White. Interview by Tom LaPuzza, August 14, 2018
Douglas Wilcox. Director of Navy Laboratories History Study interview by A.B. Christman, March 13, 1978
Dr. Howard A. Wilcox. Director of Navy Laboratories History Study interview by A.B. Christman, March 15, 1978

Government Studies/Reports

Defense Advanced Research Projects Agency, *A History of the ARPANET: The First Decade*, 1 April 1981

Defense Communications Agency, "ARPANET Information Brochure," 13 March 1978

Department of the Navy. "Report of the Committee on Organization of the Department of the Navy," 31 January 1959

Department of the Navy. *Report of the Deep Submergence Systems Review Group*, NAVEXOS P-2452, March 1964

Department of the Navy. "Research and Development Management Study," *Review of Management of the Department of the Navy*, Volume II, Study 3, 19 October 1962

Department of the Navy. *Review of Navy R&D Management 1946-1973*, June 1, 1976

Director of Defense Research and Engineering. "DoD Utilization Study," April 28, 1975

Hammond, Captain P.H., USN. U.S. Navy Radio and Sound Laboratory Biweekly Reports 1-55, 6 March 1943 – 9 June 1945

Morse, Robert W. "On the Management of Navy Laboratories," 4 January 1965

Naval Material Command. “Report of the Task Group for the Point Loma Laboratories,” January 1976 (“Goland Report”)

Naval Material Command. “Task Group Laboratory Utilization Study for the Naval Underwater Systems Center,” 16 September 1975 (“Sebestyen Report”)

NELC/NUC letter of 15 April 1976 to Chief of Naval Material, Subj.: “Plan for Consolidation of Naval Electronics Laboratory Center and Naval Undersea Center; submission of”

Office of the Director of Defense Research and Engineering. “Report of the Task Group of Defense In-House Laboratories,” Washington, D.C., 1 July 1971

Sherwin, Chalmers. “A Plan for the Operation and Management of the Principal DOD In-House Laboratories,” November 16, 1964

University of California Division of National Defense Research/Division of War Research Bi-Weekly Reports, 1941-1945

U.S. Department of Defense Task Force 97 Action Group. “Review of Defense Laboratories: Progress Report and Preliminary Recommendations,” (“Fubini Report”) September 1961

INDEX

A

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

B

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

C

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

D

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

G

Numbers in **bold** designate photographs, maps, and other illustrations

H

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

N

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

O

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

S

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations

---

Numbers in **bold** designate photographs, maps, and other illustrations