

Bernie needs a drive.

9. Naval Ship Systems Command, Recovery of Deep Research Vehicle ALVIN, NAVSHIPS 0994-004-5010, December 1969.
10. Ford, J. M., NSRDC and the New ALVIN, Naval Research Reviews, pp. 9-19, January 1974.
11. Reem, G., New Tools for ALVIN, Naval Research Reviews, pp. 20-28, December 1975.

V. List of U.S. Navy Reports

1. Cobb, A. D., ALVIN Operations, August and September 1965 at Bermuda (U), USL Tech. Mem. No. 906-01-66, Navy Underwater Sound Laboratory, 31 pp., March 1966 (CONFIDENTIAL).
2. Mullarkey, W. E. and Cobb, A. D., ARTEMIS Module Field Survey by ALVIN (U), USL Tech. Mem. No. 2214-040-66, Navy Underwater Sound Laboratory, 60 pp., Oct. 1966 (CONFIDENTIAL).
3. Austin, R. S., Exploring AUTEC Depths with ALVIN (U), TR No. 16 Naval Underwater Weapons Research and Engineering Station, 59 pp., March 1968 (CONFIDENTIAL).
4. Busby, R. F. and Merrifield, R., Undersea Studies with DSRV ALVIN, Tongue of The Ocean, Bahamas, September 1966, IR No. 67-51, Naval Oceanographic Office, 52 pp., July 1967.
5. Breaker, L. C. and Winokur, R. S., The Variability of Bottom Reflected Signals Using the Deep Research Vehicle ALVIN, IR No. 67-92, Naval Oceanographic Office, 22 pp., December 1967.
6. Howell, E. T., Jr. and Gouze, M. W., Radiated-Noise Measurements of the ONR Deep-Submergence Research Vehicle ALVIN (U), USL Report No. 930, Navy Underwater Sound Laboratory, 40 pp., August 1968 (CONFIDENTIAL).
7. Donnelly, J. D., 1967-ALVIN's Year of Science, Naval Research Reviews, pp. 18-26, January 1968.
8. Ellinthorpe, A. W. and Malone, R. G., A Visual Ocean Bottom Survey Off The Island of Santa Maria, Azores, USL Report No. 1017, Navy Underwater Sound Laboratory, 11 pp., April 1969.

More recently, inspections, surveys, and recoveries of naval equipment have been conducted in the Tongue of the Ocean and nearby areas. The Naval Undersea Center, The Naval Facilities Command and the Naval Air Development Center participated in these dives, which utilized a portion of each diving season during the period 1974 through 1976.

J. M. Ford (10), Public Relations Officer at the Naval Ship Research and Development Center, summarized the rebuilding of ALVIN under Project TITANES, emphasizing the major role of NSRDC in the total program.

G. Reem (11) of Raytheon Corporation accompanied ALVIN and LULU to the AUTEC Range, Andros Island, in 1975. He has described three new systems that have improved ALVIN's capabilities: the Wide Angle Illumination System, the Modular Sonar, and the Self-Contained Ancillary Modular Platform.

In August and September of 1966 the Tongue of the Ocean in the Bahamas was the scene of underwater acoustic studies by personnel of the Naval Oceanographic Office. Busby and Merrifield (4) and Breaker and Winokur (5) reported on the observations and measurements made during 13 ALVIN dives.

On October 24, 1967, D. Potter of the Navy Underwater Sound Laboratory accompanied by W. Marquet of W.H.O.I. made measurements of ALVIN's radiated noise when submerged. Howell and Gouze (6) reported the results of this investigation.

Lt. Cdr. J. D. Donnelly (7) of the Office of Naval Research summarized ALVIN's scientific activities for the year 1967.

A seamount survey was conducted near the Azores during August and September of 1968. Navy Underwater Sound Laboratory personnel made 12 dives to survey the geological features of this Mid-Atlantic Ridge area. Ellinthorpe and Malone (8) have reported on these dives.

The loss of ALVIN occurred in October 1968, and the recovery was completed in August 1969. A 145 page report on the recovery operation was prepared by the Naval Ship Systems Command (9).

IV. Summary of U.S. Navy Dives

U.S. Navy utilization of ALVIN began early in the life of the submersible. Almost as soon as the vehicle had been made operational and the personnel fully trained, engineers from the Navy Underwater Sound Laboratory were making dives in the Bermuda area for underwater acoustic studies. Cobb (1) reported on these activities conducted in August and September of 1965.

The loss of a nuclear weapon in the crash of a U.S. military aircraft off the coast of Spain in early 1966 brought ALVIN and LULU to the scene at the Navy's request. Working with Reynolds Metals' ALUMINAUT, ALVIN made 35 dives during the search. The weapon was found at a depth of 1900 feet, and the successful recovery operation took place on April 7, 1966.

Further Navy dives were made in the Bermuda area early in July 1966. Mullarkey and Cobb (2) presented the results of the ARTEMIS module inspection conducted during that period. In late July 1966, R. Austin (3) of the Naval Underwater Weapons Research and Engineering Station participated in three ALVIN dives near Goulding Cay, Bahamas, to inspect and photograph an AUTEC cable.

85. Jannasch, H. W., Studies on Undecompressed Microbial Populations From The Deep Sea, Appl. Environ. Microbiology (in press).
86. Jannasch, H. W. and Wirsen, C. O., Concentrating and Retrieving Micro-organisms From the Deep Sea Under Pressure, Appl. Environ. Microbiology (in press).
87. Wirsen, C. O and Jannasch, H. W., The Decomposition of Solid Organic Materials in The Deep Sea, Environmental Science and Technology (in press).
88. Jannasch, H. W. and Wirsen, C. O., Transformation Activities of Undecompressed Natural Populations of Deep-Sea Microorganisms (In preparation).
89. Dyer, R. S., Environmental Surveys of Two Deepsea Radioactive Waste Disposal Sites Using Submersibles, IAEA Paper SM-207/65, IAEA Symposium, Vienna, Austria, March 1976.
90. Cacchione, D. A., Rowe, G. T. and Malahoff, A., Sediment Processes Controlled by Bottom Currents and Faunal Activity in Lower Hudson Submarine Canyon, Presented at AAPG-SEPM Annual Convention, Symposium on Submarine Canyons, New Orleans, Louisiana, May, 1976.
91. Ballard, R. D., Window on Earth's Interior - The Cayman Trough, National Geographic Magazine, August, 1976 Issue (in press).

75. Moore, J. G., Mechanism of Formation of Pillow Lava, Amer. Sci., Vol. 63, pp. 269-275, 1975.
76. Ballard, R. D. and van Andel, T., Project FAMOUS: Morphology and Tectonics of The Inner Rift Valley at 36°50'N on The Mid-Atlantic Ridge (submitted to Geol. Soc. Amer. Bull.).
77. Ballard, R. D. and van Andel, T., Project FAMOUS: Operational Techniques and American Submersible Operations (submitted to Geol. Soc. Amer. Bull.).
78. Bryan, W. B. and Moore, J. G., Compositional Variations of Young Basalts in The Mid-Atlantic Rift Near 36°49'N. (submitted to Geol. Soc. Amer. Bull.).
79. Fenn, U., Siegel, M. D., Robinson, G. R., Holland, H. D., Williams, D. L., Erickson, A. J. and Green, K. E., Water Temperatures in the FAMOUS Area (In preparation).
80. Heirtzler, J. R. and van Andel, T., Project FAMOUS: Origin, Programs and Setting (submitted to Geol. Soc. Amer. Bull.).
81. Johnson, P. and Atwater, T., A Magnetic Study of the Basalts from the Mid-Atlantic Ridge at 37°N. (submitted to Geol. Soc. Amer. Bull.).
82. Williams, D. C., Tien-chang Lee, Green, K., Von Herzen, R. P. and Hobart, M. A., A Geothermal Study of The Mid-Atlantic Ridge Near 37°N. (In preparation).
83. Schlager, W., Hooke, R. and James, N., Episodic Erosion and Deposition in The Tongue of The Ocean, Bahamas, Geology (In press).
84. Staiger, J., Aspects of The Biology of The Benthic Fishes of The Tongue of The Ocean, Copeia (In press), Presented at Am. Soc. Ichthyol. and Herpetol. Ann. Mtg., Williamsburg, Va., June 8-15, 1975.

64. Ballard, R. D., Bryan, W. B., Heirtzler, J. R., Keller, G. H., Moore, J. G., van Andel, T., Manned Submersible Observations in the FAMOUS Area Mid-Atlantic Ridge, Science, Vol. 190, pp. 103-108, 1975.
65. Ballard, R. D., Project FAMOUS II - Dive into the Great Rift, National Geographic Magazine, Vol. 147, No. 5, pp. 604-615, 1975.
66. Ballard, R. D., Photography From a Submersible During Project FAMOUS, OCEANUS, 31-39, Spring, 1975.
67. Ballard, R. D., Improving the Usefulness of Deep-Sea Photographs With Precision Tracking, OCEANUS, 40-43, Spring 1975.
68. Ballard, R. D., Probing The Mid-Atlantic Rift, The Science Teacher, Vol. 42, pp. 12-17, Sept. 1975.
69. Drake, C. L., Heirtzler, J. R., Oliver, J. E., Geodynamics Project Initial Development in The U.S. Program, Review of Geophysics and Space Physics, Vol. 13, pp. 105-6, 1975.
70. Heirtzler, J. R., Project FAMOUS Planning Mid-Atlantic Ridge Investigation, Marine Tech. Soc. Jour., Vol. 7, No. 1, pp. 14-15, 1973.
71. Heirtzler, J. R. and Le Pichon, X., FAMOUS: A Plate Tectonics Study of The Genesis of The Lithosphere, Geology, Vol. 2, No. 6, pp. 273-378, 1974.
72. Heirtzler, J. R., Project FAMOUS - Man's First Voyages Down to The Mid-Atlantic Ridge - Where the Earth Turns Inside Out, National Geographic Magazine, Vol. 147, No. 5, pp. 587-603, 1975.
73. Heirtzler, J. R. and Bryan, W. B., The Floor of The Mid-Atlantic Rift, Scientific American, Vol. 233, No. 2, 1975.
74. Heirtzler, J. R., Project FAMOUS, Review of Geophysics and Space Physics, Vol. 13, p. 5, 1975.

55. Ballard, R. D., Summary of Seismic Reflection, Refraction, Magnetic and Dredge Station Data Collected During a Geologic Study of the Gulf of Maine, W.H.O.I. Ref. No. 74-30, 87 pp., 1974.
56. Ballard, R. D. and Uchupi, E., Triassic Rift Structure in the Gulf of Maine, Am. Assoc. Petr. Geol. Bull., Vol. 59, pp. 1041-1072, 1975.
57. Rowe, G. T., The Effects of Benthic Fauna on the Physical Properties of Deep-sea Sediments, In: Deep Sea Sediments, Edited by A. L. Underbitzen, Plenum Pub. Corp., pp. 381-400, 1974.
58. Rowe, G. T., Keller, G., Edgerton, H., Staresinic, N. and MacIvaine, J., Time-Lapse Photography of the Biological Reworking of Sediments in Hudson Submarine Canyon, Journal Sed. Petr., Vol. 44, No. 2, pp. 549-552, 1974.
59. Keller, G. H., Lambert, D., Rowe, G. T. and Staresinic, N., Bottom Currents in The Hudson Canyon, Science, Vol. 180, No. 4082, pp. 181-183, 1973.
60. Grassle, J. F., Sanders, H. L., Hessler, R. R., Rowe, G. T. and McLellan, T., Pattern and Zonation: A Study of The Bathyal Megafauna Using The Research Submersible ALVIN, Deep Sea Research, Vol. 22, pp. 457-481, 1975.
61. Emery, K. O. and Uchupi, E., The Western North Atlantic Ocean: Topography, Rocks, Structure, Water, Life, and Sediments, Memor. Amer. Assoc. Petrol. Geol., Vol. 17, 532 pp., 1972.
62. Wirsen, C. O. and Jannasch, H. W., Activity of Marine Psychrophilic Bacteria at Elevated Hydrostatic Pressures and Low Temperature, Marine Biology, Vol. 31, p. 201, 1975.
63. Anderson, S. H., Man's First Look at The Mid-Ocean Ridge, NOAA, Vol. 5, No. 1, pp. 12-17, 1975.

46. Rowe, G. T., The Exploration of Submarine Canyons and Their Benthic Faunal Assemblages, Proc. Roy. Soc. Edin. (B) Vol. 73, No. 17, pp. 159-169, 1972.
47. Pollont, P. T., Rowe, G. T., Teal, J. M., Biremis Blandi (Polychaeta: Terebellidae), New Species Caught by DSRV ALVIN in the Tongue of the Ocean, New Providence, Bahamas, Marine Biology, Vol. 20, No. 2, pp. 170-175, 1973.
48. Grice, G. D., Alrhabdus johrdae, A New Genus and Species of Benthic Calanoid Copepod From The Bahamas, Bull. Mar. Sci., Vol. 23, No. 4, pp. 942-947, 1974.
49. Rowe, G. T., Pollont, P. T. and Haedrich, R. L., Quantitative Biological Assessment of The Benthic Fauna in Deep Basins of The Gulf of Maine, Journal Fish. Res. Board Can., Vol. 32, No. 10, pp. 1805-1812, 1975.
50. Jannasch, H. W. and Wirsen, C. O., Deep-Sea Microorganisms: In Situ Response to Nutrient Enrichment, Science, Vol. 180, No. 4068, pp. 641-643, 1973.
51. Jannasch, H. W. and Wirsen, C. O., Microbial Transformations of some ^{14}C Labeled Substrates in Coastal Water and Sediment, Microbial Ecology, Vol. 1, pp. 25-37, 1974.
52. Terry, T. A. and Richards, A. F., Mechanical Engineering, Geotechnology and Research Submersible Operations, ASME Ann. Mtg. Ocean Techn. Div. Paper No. 73-WA/Oct-11, 8 p., 1973.
53. Keller, G. H., Sedimentary Dynamics Within The Hudson Submarine Canyon (abs), Proceedings of Symposium on Interrelationships of Estuarine and Continental Shelf Sedimentation, 1973.
54. Ballard, R. D., Summary of The Geologic Dives Conducted in The Gulf of Maine During 1971 and 1972 by The Research Submersible ALVIN, W.H.O.I. Ref. No. 74-29, 73 pp., 1974.

37. Hirst, T. J., Perlow, M., Richards, A. F., Burton, B. S. and van Scliver, W. J., Improved In Situ Gamma-Ray Transmission Densitometer for Marine Sediments, Ocean Engineering, Vol. 3, pp. 17-27, 1975.
38. Richards, A. F., Standardization of Marine Geotechnics Symbols, Definitions, Units, and Test Procedures, Deep-Sea Sediments: Physical and Mechanical Properties, A. L. Inderbitzen, ed., Plenum Press, New York, (in press).
39. Ballard, R. D. and Uchupi, E., Geology of the Gulf of Maine, Am. Assn. Petro. Geol. Bull. Vol. 58, No. 6, Pt. II of II, pp. 1156-1158, 1974.
40. Ballard, R. D., Uchupi, E., Carboniferous and Triassic Rifting: A Preliminary Outline of the Tectonic History of the Gulf of Maine, Bull. Geol. Soc. Amer., Vol. 83, No. 4, pp. 2285-2302, 1972.
41. Turner, R., Wood-Boring Bivalves, Opportunistic Species in the Deep Sea, Science, Vol. 180, pp. 1377-1379, June 1973.
42. Smith, K. L. and Teal, J. M., Deep Sea Benthic Community Respiration: An In Situ Study at 1850 Meters, Science, Vol. 179, No. 4070, pp. 282-283, 1972.
43. Oldale, R. N., Uchupi, E., Prada, K. E., Sedimentary Framework of the Western Gulf of Maine and The Southern Eastern Massachusetts Offshore Area, U.S. Geol. Surv. Prof. Pap. No. 757: 10 pp., 2 pls. 1 fig., 1973.
44. Winter, L. T., Keller, G. H. and Pyle, T. E., Morphology and Sedimentary Processes in and Around Tortugas and Agassiz Sea Valleys, Southern Straits of Florida, Marine Geology, Vol. 18, pp. 47-69, 1975.
45. Rowe, G. T. and Clifford, C. H., Modifications of the Birge-Ekman Box Core for Use With SCUBA or Deep Submergence Research Vessels, Limnol. Oceanogr., Vol. 18, No. 1, pp. 172-175, 1973.

29. Jannasch, H. W., Wirsén, C. O. and Winget, C. L., A Bacteriological Pressure-Retaining Deep-Sea Sampler and Culture Vessel, Deep-Sea Research, Vol. 20, No. 7, pp. 661-664, 1973.
30. Richards, A. F., Instrumentation of Two Submersibles for In Situ Geotechnical Measurements in Cohesive Sea Floor Soils, Preprints 2nd Int. Ocean Dev. Conf., Tokyo, Vol. 2, pp. 1329-1346, 1972.
31. Richards, A. F., McDonald, V. J., Olson, R. E. and Keller, G. H., In-Place Measurement of Deep Sea Soil Shear Strength, Underwater Soil Sampling, Testing, and Construction Control, ASTM STP 501, American Society for Testing and Materials, pp. 55-68, 1972.
32. Hirst, T. J., Kelleman, J. L., Jr. and Terry, T. A., Submersible Mounted Geotechnical Probes, 8th Annual Conference Preprints, Marine Technology Society, pp. 601-614, 1972.
33. Perlow, M. and Richards, A. F., In Place Geotechnical Measurements From Submersible ALVIN in Gulf of Maine Soils, Paper No. OTC 1543, 8 pp. Presented at the Fourth Annual Offshore Technology Conference, Houston, Texas, May 1-3, 1972.
34. Perlow, M. and Richards, A. F., Geotechnical Variability Measured in Place From A Small Submersible, Marine Technology Society Journal, Vol. 7, No. 4, pp. 27-32, 1973.
35. Perlow, M., Jr., Influence of Sample Disturbance and Test Method on Key Engineering Properties of Marine Soils, M.S. Thesis, Dept. of Civil Engineering, Marine Geotechnical Laboratory, Lehigh University, 1974.
36. Perlow, M., Jr. and Richards, A. F., Sampling Densification in Marine Clayey-silts, EOS Transactions, Amer. Geophysical Union, Vol. 55, No. 4, p. 313, 1974.

19. Schevill, W. E. and Watkins, W. A., Natural Sounds of The Sea, In: W.H.O.I. Ref. No. 69-13, p. 80, 1969.
20. Ross, D. A., Geological Observations from ALVIN, W.H.O.I. Ref. No. 69-13, pp. 71-72, 1969.
21. Ross, D. A., Atlantic Continental Shelf and Slope: Heavy Minerals of the Continental Margin From Southern Nova Scotia to Northern New Jersey, U.S. Geol. Survey Prof. Paper 529-G, 40 pp., 1970.
22. Grice, G. D. and Hulsemann, K., New Species of Bottom-Living Calanoid Copepods Collected in Deep-water by the DSRV ALVIN, Bull. Mus. Comp. Zool., 139(4) pp. 185-230, 1970.
23. Grice, G. D., The Existence of a Bottom-Living Calanoid Copepod Fauna in Deepwater with a Description of Five New Species, Crustaceana Vol. 23, No. 3, pp. 219-242, 1972.
24. Uchupit, E., Phillips, J. D., Prada, K. E., Origin and Structure of The New England Seamount Chain, Deep-Sea Research, Vol. 17, No. 3, pp. 483-494, 1970.
25. Ballard, R. D. and Emery, K. O., Research Submersibles in Oceanography, Marine Technology Society Spec. Publ., 70 pp., 1970.
26. Jannasch, H. W. and Wirsen, C. O., ALVIN and the Sandwich Woods Hole Oceanographic Institution, OCEANUS XVI: 20-22, 1972.
27. Jannasch, H. W., Eimhjellen, K., Wirsen, C. O. and Farmanfarman, A., Microbial Degradation of Organic Matter in The Deep Sea, Science, Vol. 171, No. 3972, pp. 672-675, 1971.
28. Jannasch, H. W. and Eimhjellen, K., Studies of The Bio-Degradation of Organic Materials in The Deep-Sea, In: Marine Pollution and Sea Life, FAO Conference on Marine Pollution, M. Ruivo, Editor, London, 1972.

10. Trumbull, J. V. A., and Hathaway, J. C., Further Exploration of Oceanographer Canyon, W.H.O.I. Ref. No. 68-37, 57 pp., 1968.
11. Gibson, T. G., Hazel, J. E., and Mello, J. F., Fossiliferous Rocks from Submarine Canyons Off Northeastern United States, U.S. Geol. Survey Prof. Paper 600-D, 8 pp., 1968.
12. Wigley, R. L., Can Submersible Vehicles be Used Effectively in Studies of Cold Water Shelf Fisheries?, Fishing News International, Vol. 7, pp. 32-34, 1968.
13. Wigley, R. L., and Emery, K. O., Submarine Photos of Commercial Shellfish Off Northeastern United States, Commercial Fisheries Review, Vol. 30, pp. 43-49, 1968.
14. Ross, D. A., Current Action in a Submarine Canyon, Nature Vol. 218, No. 5148, pp. 1242-1244, 1968.
15. Backus, R. H., Craddock, J. E., Haedrich, R. L., Shores, D. L., Teal, J. M., Wing, A. S., Mead, G. W., Clarke, W. D., Ceratocopelus Maderensis. Peculiar Sound-Scattering Layer Identified with this Myctophid Fish, Science, Vol. 160, No. 3831, pp. 991-993, 1968.
16. Emery, K. O., Ross, D. A., Topography and Sediments of a Small Area of the Continental Slope South of Martha's Vineyard, Deep-Sea Research, Vol. 15, pp. 415-422, 1968.
17. Sanders, J. E. and Clay, C. S., Investigation of the Ocean Bottom With Side Scanning Sonar, Proc. of Symposium on Remote Sensing of Environment, Institute of Science and Technology, Willow Run Laboratories, University of Michigan, 1968.
18. Sanders, J. E., Emery, K. O., and Uchupi, E., Micro-Topography of Five Small Areas of the Continental Shelf by Side Scanning Sonar, Bull. Geol. Soc. Amer., Vol. 80, No. 4, pp. 561-572, 1969.

III. List of Scientific Publications

1. Schlee, J., Geology from a Deep-Diving Submersible, Geotimes Vol. 12, No. 4, pp. 10-13, 1967.
2. Gibson, T. G. and Schlee, J., Sediments and Fossiliferous Rocks from the Eastern Side of the Tongue of the Ocean, Bahamas, Deep-Sea Research, Vol. 14 pp. 691-702, 1967.
3. Rooth, C. G. H., Studies of Convective Motion and of Turbulent Mixing Processes in a Stratified Environment, In: W.H.O.I. Ref. No. 67-15, pp. 249-250, 1967.
4. Trumbull, J. V. A., McCamts, M. J., Geological Exploration in an East Coast Submarine Canyon from a Research Submersible, Science Vol. 158, No. 3799, pp. 370-372, 1967.
5. Milliman, J. D., Manheim, F., Pratt, R. M., Zarudski, E. F., K., ALVIN Dives on the Continental Margin Off The South-Eastern United States, July 2-13, 1967, W.H.O.I. Ref. No. 67-80, 64 pp. 1967.
6. Milliman, J. D., Manheim, F. T., Observations in Deep-Scattering Layers Off Cape Hatteras, Deep-Sea Research Vol. 15, pp. 505-507, 1968.
7. Zarudski, E. F., K., Swordfish Rams the ALVIN, OCEANUS XIII (4): 14-18, Woods Hole Oceanographic Institution. Oct. 1967.
8. Edwards, R. L., Emery, K. O., The View from a Stored Sub: The ALVIN Off Norfolk, Va., Commercial Fisheries Review Vol. 30 Nos. 8-9, pp. 48-55, 1969.
9. Emery, K. O., Positions of Empty Pelagic Valves on the Continental Shelf, J. Sed. Petrology. Vol. 38, pp. 1264-1267, 1968.

and in the harbor at Guantnamo, Cuba, during which post-overhaul checkouts and certification testing were completed. Late in January, geological work funded by NSF began in the Cayman Trench. Scientists R. Ballard (91), J. de Boer, J. Fox, R. Wright, W. Sullivan, K. Emery, T. van Andel, J. Corliss and photographer E. Kristof participated in these 15 dives in which some 500 pounds of rock samples were collected. The St. Croix Range studies began in mid-March with observers Dill, Gardner, Sutherland, Ballew, Williams, and Kirkpatrick involved in inspections of underwater installations for the U.S. Navy. Early in April Dr. Bruce Heezen assisted by M. Rawson, W. Nesterhoff, and R. Lynde conducted a series of geology dives in waters off Puerto Rico and the Dominican Republic. Later, Dr. Ruth Turner made two biology dives in the Tongue of the Ocean. Further inspection and search activities for the U.S. Navy followed, and the spring operating season ended on 28 April with dive number 653.

trap was recovered. W.H.O.I. scientists G. Rowe, R. Turner, P. Polloni, K. Smith, H. Sanders, N. Staresinic, and R. Harbison made these dives, accompanied by D. Cacchione of the U.S.G.S. and A. Malahoff of ONR. Cacchione, Rowe and Malahoff (90) have reported on some of the work accomplished during this series, which brought the 1975 operating season to a close.

G. Keller, R. Cooper, J. Uzmann and D. Lambert made four dives for NOAA during which biological and geological observations were made. Three UNOLS-sponsored biology dives followed in early July in which scientists K. Smith, C. Wirsen (85, 86, 87, 88), M. Rex, F. Grassle, and R. Carney took samples, recovered a prior-installed bottom station tower, and set two new towers. Ten biology dives were sponsored by NOAA in which investigators R. Dyer (89), D. Cohen, H. Clifford, D. Pawson, J. Mustick, R. Gibbs, and C. Karnella located radio-active waste containers and made a survey of the dump site about 150 miles east of Cape May, New Jersey. Also during this series, biological characterization studies were conducted, and a scattering layer species count was made. Biology work continued during late August and early September with a series of eleven dives. These UNOLS-funded dives were made in the Hudson Canyon area. Activities included the emplacement of wood specimens, pingers, and mud boxes. In addition, core samples were taken and a sediment

1975 - Scientific diving began in mid-April with four dives in the Tongue of the Ocean. Sponsored by the University-National Oceanographic Laboratory System (UNOLS), these dives were made by scientists L. Cole, S. Garner, M. Rex, and Ruth Turner. Biological observations centered around a bottom station at a depth of 2043 meters. In the same location and under the same sponsorship four geology dives were made by investigators N. James, R. Hooke, and W. Schlager (83). Four more biology dives followed (also UNOLS); observers were J. Stager (84), C. Messing, K. Sulak, and P. Colin. After a number of engineering dives which occupied the first two weeks of May, a series of five geology dives were made by observers G. Keller, W. Stubblefield, G. Lambert, P. Fox, and G. Lapiene. These dives, under NOAA funding, were made in an area just west of Great Abaco Island, Bahamas. Dive No. 569, one of this series, was the first ocean dive to a depth of 1200 feet. Two biology dives were then conducted by scientists J. Musick, C. Wanner, and D. Markle for NSF. Late in June investigators

sponsorship to the Hudson Canyon area, and to the W.H.O.I. bottom station south of Cape Cod. On 6 October after a year's total of 60 dives, ALVIN went into annual overhaul, scheduled for completion on 1 March 1975.

From 19 June until its return to Woods Hole on 3 September ALVIN made a total of 27 dives. Of these, 17 were for the FAMOUS project on the Mid-Atlantic Ridge. Anderson (63), Ballard, *et al* (64), Ballard (65, 66, 67, 68), Drake (69), Heirtzler (70), Heirtzler and Lepichon (71), Heirtzler (72), Heirtzler and Bryan (73), Heirtzler (74) and Moore (75) have published their findings covering a variety of Mid-Atlantic Ridge observations. In addition, Ballard and van Andel (76, 77), Bryan and Moore (78), Fenn, *et al* (79), Heirtzler and van Andel (80), Johnson and Atwater (81) and Williams, *et al* (82) have ALVIN-related FAMOUS contributions in press or in preparation at this writing. Following the FAMOUS activities, ALVIN made one dive to inspect a defective acoustic array for the Navy, one for the Deep Sea Drilling Project, one for vehicle test, and a series of seven dives for ONR during which each dive was made to a different seamount in the New England Seamount Chain. In September and October, two short cruises were made under NOAA

1974 - On 1 January 1974, DSRV ALVIN embarked on RV LULU, was underway from Ft. Pierce, Florida en route to Nassau, New Providence Island, Bahamas. During the period 1 January through 9 March, six cruises were made operating out of Nassau and Andros Island. Work accomplished included current studies, biology, and recovery and inspection work for the U.S. Navy. During this period Carl Wirsen (62) conducted studies of the activity of marine bacteria at high pressures. In addition, training dives were made for the FAMOUS (French American Mid-Ocean Undersea Study) Program and tests of new penetrator installation configurations were made which included a dive to 10,000 feet. ALVIN and LULU arrived back in Woods Hole on 21 March and preparations were begun for the FAMOUS operation. These preparations included a short cruise off Provincetown for shallow trials in May. On 6 June with ALVIN on deck and LULU towing astern, RV KNORR got underway for the Azores and Project FAMOUS. Upon arrival at Ponta Delgada, Azores, on 18 June, ALVIN was transferred to LULU.

1973 - The period November 1972 through June 1973 was set aside for the refitting of ALVIN with the new titanium pressure hull provided under Project TITANES. The operation of the rebuilt vehicle began in July with pressure tank tests at the Naval Ship Research and Development Center (NSRDC) at Annapolis, Maryland. Two unmanned tests, and one manned test, were made, all to the pressure equivalent of 12000 feet. The manned test constituted the required certification deep dive. Following the usual dockside tests in Woods Hole, further test and training dives were made, during August and September, in Province-town harbor and nearby waters. Training and test dives continued into October in the Woods Hole and Provincetown areas. Similar diving activity was resumed in waters off West Palm Beach, Florida, during November and early December.

dives were made in September by G. Keller, N. Staresinic, and D. Lambert of NOAA, and by W. Van Sciver and R. Swartz of Lehigh University. Seven dives were devoted to current measurement, sediment density determination, and sampling (57, 58, 59). Five NSF-funded biology dives at the bottom station 100 miles south of Martha's Vineyard completed the scientific diving season. Observations were made and samples obtained by investigators H. Sanders, T. McLellan, F. Grassle (60), P. Holmes and G. Hampson, of W.H.O.I., and J. Drogou of CNEXO, France. The year 1972 saw the publication of a book by K. O. Emery and E. Uchupi (61) which presents a comprehensive treatment of the geological aspects of the western North Atlantic Ocean area. In November the major disassembly of ALVIN was begun, to prepare for the installation of the new titanium pressure hull.

navigation experiments. Magnetometer and rock hammer trials were conducted by Dr. R. Ballard of W.H.O.I., and A. Malahoff and J. Carlmark of ONR. Late in July eight geology dives were made under NSF funding, all in the Gulf of Maine. Participating scientists were W. Bryan, L. King, R. Ballard, R. McMasters and G. Hayward. Rock samples were collected and various geological observations were made. ALVIN and LULU then returned to Woods Hole for about one week for minor repairs and routine maintenance. Early in August, six ONR-funded biology dives were made at a point about 100 miles south of Martha's Vineyard (bottom station). Scientists G. Rowe, D. Cohen, K. Smith, J. MacIvaine, P. Wiebe and C. Clifford planted bell jars and made plankton tows. The remainder of August was given over to ARPA geology and navigation work. Seven dives were made by investigators Bryan, Heitzler, Ballard of W.H.O.I., and Bellache (CNEOXO, France) in the Gulf of Maine. Ballard (54, 55) and Ballard and Uchupi (56) reported on the results of the geological observations. Hudson Canyon geology

pleting the annual overhaul, and diving op-

erations commenced in May. A total of 67 dives

were made; 21 of these were for test, training,

certification, and certain scientific missions

with separate funding. In May, following the

usual vehicle tests and a certification dive to

1833 m., scientific diving began with a series

of tests of the large rock drill developed at

W.H.O.I. under the ARPA program. Also sponsored

by ARPA, Drs. G. Rowe and R. Haeckel made two

biology dives in the Gulf of Maine. These were

followed by a series of four NSF biology dives

by Carl Wirsen, Drs. T. McEllen, P. Wiebe, K.

Smith, R. Turner and F. Grassle (50, 51). Drs.

G. Keller, G. Rowe, T. Terry and R. Ballard made

dives in the Hudson Canyon late in June for geo-

logical and biological observations (52, 53).

These eight dives, funded by NOAA, were primarily

for the purpose of sediment density determination

and the installation of bottom current meters.

Later, eight ARPA dives were made for geology and

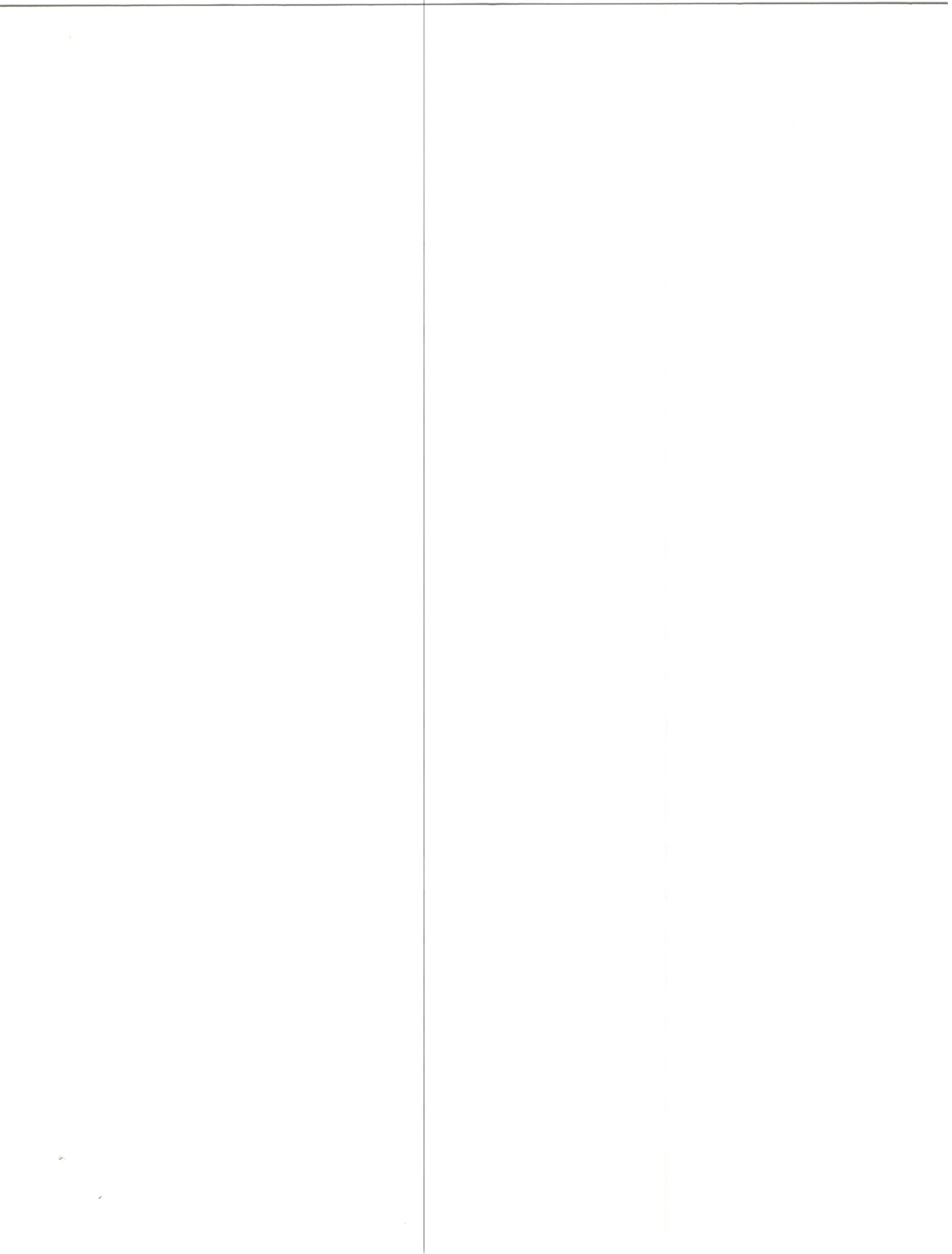
dives in the area of the Straits of Florida. In November miscellaneous dives were made in the Bahamas for W.H.O.I. biology, ONR/AUTEC, and the underwater navigation program supported by the Advanced Research Project Agency (ARPA). Drs. R. Ballard, G. Rowe and J. Teal (45, 46, 47) were observers on a number of these dives. During December further ARPA navigation testing was done and magnetic studies were made by Dr. B. Luyendyk of W.H.O.I., including a successful test of a new magnetometer. David Williams and Andrew Barrs successfully tested a large rock drill capable of making cores three feet in length, and Dr. G. Grice of W.H.O.I. and Dr. Mary Johrde of the National Science Foundation (NSF) ran plankton tows (48). Finally, a successful recovery of Naval ordnance hardware was made from a depth of 1545 meters.

sediment properties investigations, also in the Gulf of Maine. On July 18th a series of geology dives began in the Gulf of Maine. R. Ballard (39, 40) and D. Ross of W.H.O.I., Dr. L. King of Bedford Institute, and Dr. M. Kane of United States Geological Survey (USGS) obtained hard rock cores using the rock drill developed by W.H.O.I. engineers. They also surveyed the area, and obtained over 150 pounds of rock samples. Early in August Doctors Ruth Turner and John Teal (41, 42) conducted biology dives near Cape Cod. Later that month, and during most of September the new submersible navigation system was tested. Early in October further Gulf of Maine geology dives were made by R. Ballard and R. Oldale (43) and a buoy line recovery was attempted for the Office of Naval Research (ONR). The remainder of October was used almost entirely for geology dives sponsored by the National Oceanic and Atmospheric Administration (NOAA) and ONR. D. Florwicz, D. Lambert, G. Keller (44), J. Kofoed and G. Hood of NOAA, and Dr. C. Neumann of the University of Maine participated in these

1971 - The rebuilding of ALVIN was completed in May 1971, following its loss in October 1968, and its subsequent recovery in August 1969. At that time it was discovered that food materials in the crew's lunch box were in a surprisingly well preserved state after exposure for more than ten months to deep sea conditions. This led W.H.O.I. biologists to begin a series of experiments to substantiate this observation. H. W. Jannasch, et al (26, 27, 28, 29) reported their findings in several scientific journals. Following a series of test dives in the Woods Hole area, and a 6000 ft. certification dive about 100 miles south of Martha's Vineyard, a program of biology dives was begun on June 17th. F. Grassle, K. Smith, J. Craddock, R. Beamis, G. Rowe, and D. Bumpus participated in plankton tow and benthic survey experiments south of Martha's Vineyard, and in the Gulf of Maine. During the first week of July, Lehigh University researchers T. Nixon, A. Richards, J. Van Sciver, M. Perlow, and T. Terry (30, 31, 32, 33, 34, 35, 36, 37, 38) conducted a series of penetrometer tests and bottom

1968 - A series of dives were conducted in April to attempt observation of Right Whales for W. E. Schevill. Results of these dives contributed to the study then being conducted by Schevill and Watkins (19) of naturally occurring sounds in the ocean. In addition to many test and engineering dives in May, Mr. John Hughes of the Massachusetts Department of Natural Resources made a dive to observe lobsters. Toward the end of May three dives were made for Dr. John Schlee and Dr. John C. Hathaway for geological survey. Two geological dives were made in June for Dr. D. A. Ross (20, 21) and Dr. John Hathaway, and three biological dives were made for Dr. Robert Hessler. In July four dives were made to collect plankton for Dr. G. Grice (22, 23) and two dives were made on Bear Sea Mount for Dr. K. O. Emery (24, 25). All of August was spent conducting dives for the Navy. Two more science dives were conducted in October for Dr. R. A. Backus, to observe the deep scattering layer south of Martha's Vineyard.

by a series of biological dives by R. H. Backus, et al (15) in which the deep sound-scattering layer was studied. In October K. O. Emery and D. A. Ross (16) made four dives with the dual purpose of searching for the lost ALVIN manipulator and making geological observations. J. E. Sanders (of Hudson Laboratories), and K. O. Emery (17, 18) investigated the ocean bottom using side-scanning sonar in an area south of Cape Cod, to complete the year's diving season.



1967 - After several test and certification dives, 1967 began with four more dives for NAVOCCEANO which included both geological and engineering work. In July John Milliman, Frank Mannheim, Richard Pratt and E. F. K. Zarudski (5, 6, 7) made a series of dives on the Blake Plateau and on the continental shelf northeast of Cape Hatteras. Both geological and biological observations were conducted on these dives. K. O. Emery of W.H.O.I. and R. L. Edwards of Bureau of Commercial Fisheries (8, 9) followed with two dives on the continental shelf off Chesapeake Bay, exploring submerged beaches and dunes. In August dives by J. V. A. Trumbull and J. C. Hathaway (10, 11) in Oceanographer Canyon provided new information about the formation and age of this geographical feature. Later in August R. L. Wigley of the Bureau of Commercial Fisheries made a dive on Georges Bank obtaining samples and photographs. Wigley (12), and Wigley and Emery (13) published the results of this dive. During this period D. A. Ross (14) made a dive in Corsair Canyon surveying the area and collecting samples. This was followed

1966 - While 1966 was devoted primarily to U.S. Navy missions, several geological dives were made in the Bahamas for Dr. John Schlee (1, 2) of the U.S. Geological Survey, and a 15 dive series was made for the Naval Oceanographic Office (NAVOCEANO) which included photography, coring, bottom profiling and the acquisition of biological fouling data at depths ranging from 2750 to 5500 feet. Back in New England waters, Dr. Claes Rooth (3) made measurements of the temperature microstructure at the thermocline, and Dr. James Trumbull (4) was the first geologist to directly view a deep canyon in the Atlantic continental slope.

II. Narrative of Scientific Dives

the scientific diving activities of ALVIN, and to identify these activities with the published works directly related to them.

study and similar results are to be expected from the Cayman Trough operations.

Despite the success of these and other missions it has become very clear over the years that a job-shop approach to funding the ALVIN program does not provide the continuity necessary to retain working level expertise, plan viable scientific programs, and maintain a flexible deep-ocean capability for the U.S. Navy. In order to better support this program, the Office of Naval Research (ONR), the National Science Foundation (NSF), and the National Oceanic and Atmospheric Administration (NOAA) recently have agreed to provide a base of funding each year for three years. These funds would allow the maintenance of a basic capability and provide for some scientific work. It was agreed that the selection of scientific projects under this funding would be made by an evaluation committee administered by the University-National Oceanographic Laboratory System (UNOLS).

ALVIN's contribution to the success of a scientific mission is seldom apparent at the time the work is performed. Acknowledgement comes later (often after a lapse of several years) when the results are published. Therefore, in the following sections, we have chosen to describe in some detail

that of the original HY-100 steel sphere, but the titanium alloy is about 40 percent lighter than steel. This has resulted in a new hull capable of diving to 12,000 feet (double the working depth of the steel hull) and a significant increase in payload. ALVIN was disassembled in November 1972 and the new pressure sphere was installed along with a newly built variable-ballast system required for the greater depth. In June of 1973 the rebuilding was completed and diving tests commenced in July. Scientific work was begun in January of 1974 with dives conducted at depths of 8000 to 10,000 feet on a routine basis. On 19 May 1975 ALVIN dove to 12,000 feet in the Bahamas area on a geology dive. Since that time the submersible has reached its design operating depth on numerous occasions. This new depth capability of ALVIN has resulted in its use in studies of sea floor spreading.

Two recent scientific programs are especially worthy of note: the submersible participated in the French-American Mid-Ocean Undersea Study (FAMOUS) in the summer of 1974. ALVIN made 17 dives, working closely with the French submersibles CYANA and ARCHIMEDE. In 1976 the Cayman Trough study was undertaken in which ALVIN made 15 dives. Significant scientific publications have resulted from the FAMOUS

In October 1968 ALVIN was lost in an unfortunate accident. When one of the hoisting cables parted, ALVIN slid off its elevator platform into the water. The three occupants escaped uninjured, but the submersible sank to the bottom, a depth of about 5,000 feet. Preparations for ALVIN's recovery began at once, and continued into 1969. Aided by ALUMINANT and the U.S. Navy ship MIZAR, W.H.O.I. personnel made a successful hook-up and recovery in August of that year. Most of ALVIN's major components were found to be in good condition. The main aluminum frame was corroded, and was replaced by a new frame. The sail had been badly damaged and it also required replacement. The pressure hull and buoyancy spheres needed cleaning but they were otherwise in excellent condition. Reassembly of the vehicle was completed in May 1971, and scientific diving was resumed in June of that year. ALVIN, rebuilt and using many of its original component parts, was returned to service with its former 6000 ft. depth capability for two more diving seasons.

Under the U.S. Navy's Project TITANES a new titanium alloy pressure hull was designed and built to be used in ALVIN. The new sphere has a wall thickness greater than

I. Background

The ALVIN program was initiated in 1961 under a contract

with the Office of Naval Research (ONR) of the U.S. Navy.

Using ONR funds the Woods Hole Oceanographic Institution

(W.H.O.I.) asked industry for bids to design and build a

deep-diving submarine capable of participating in programs

in underwater acoustics, ocean bottom geology, and deep-sea

biology. In 1962 a contract was signed between W.H.O.I. and

General Mills, Inc. for this undertaking. A short time later

the Applied Science Division of General Mills was purchased

by Litton Industries, who finished the project. ALVIN was

completed and commissioned in June 1964, and was considered

to be operational by the end of 1965. During that year a

series of deep dives were made which concluded with two

manned dives to the design depth of 6000 feet.

In the spring of 1966 the Navy called upon ALVIN to

assist in the search for the lost H-bomb off the coast of

Spain. ALVIN, working with the submarine ALUMINANT, made

a series of 35 dives during which the weapon was found and

recovered. Later that year ALVIN made its first deep-water

dives solely for scientific research, thus establishing a

deep-ocean capability that has continued to the present.

Table of Contents

I.	Background	1
II.	Narrative of Scientific Dives	6
III.	List of Scientific Publications	24
IV.	Summary of U.S. Navy Dives	34
V.	List of U.S. Navy Reports	37

ALVIN, a deep-submergence oceanographic research submarine, is owned by the Office of Naval Research of the U.S. Navy and operated by the Woods Hole Oceanographic Institution. Completed in 1964, it began routine diving for scientific research in 1966. Since that time the submersible has made over 650 dives in many areas of the Atlantic Ocean including the Azores, Spain, the Bahamas, the Straits of Florida and the Gulf of Maine. Many of the dives have been for vehicle test and training purposes, and a significant number have been required by the U.S. Navy for various engineering and salvage operations. These activities are discussed briefly and a short list of related technical papers is given. Nearly 300 dives have been completed for purely scientific purposes. These latter dives are described briefly in chronological order, and a list of 91 of the resulting scientific publications is presented.

ABSTRACT

Woods Hole Oceanographic Institution

DSRV ALVIN: A Review of
Accomplishments

A Report Prepared for the UNOLS Meetings
Held at the Woods Hole Oceanographic Institution
June 17-18, 1976

by

Arnold G. Sharp
and
Lawrence A. Shumaker