

OCEAN EXPLORATION COOPERATIVE INSTITUTE



Exploring the
Nation's Blue
Frontier



Executive Summary

Year Three Annual Report

(July 2021 — June 2022)



OCEAN EXPLORATION COOPERATIVE INSTITUTE



EXPLORING THE NATION'S BLUE FRONTIER

The OEI is an integrated ocean exploration enterprise that leverages the unique, world-class knowledge and expertise of its partner institutions—Ocean Exploration Trust (OET), University of New Hampshire (UNH), University of Rhode Island (URI), University of Southern Mississippi (USM) and Woods Hole Oceanographic Institution (WHOI)—and NOAA Ocean Exploration.

The OEI aims to advance ocean exploration by:

- Researching and developing new ocean-exploration vehicles, sensors and operations
- Expanding ocean exploration through multi-vehicle operations and the fielding of new technologies and operational approaches
- Reimagining approaches and infrastructure for collecting, analyzing and delivering ocean-exploration data
- Inspiring and training a new, more diverse generation of ocean explorers.

EXECUTIVE COMMITTEE

- Dr. Adam Soule
OEI Executive Director, URI
- Allison Fundis
COO, OET
- Dr. Larry Mayer
CCOM Director, UNH
- Dr. Leila Hamden
SOSE Director, USM
- Dr. Rick Murray
Vice President of Research, WHOI
- Dr. Jeremy Weirich
Director, NOAA Ocean Exploration

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- Jason Fahy (*Chair*)
OEI Associate Director, URI
- Dr. Daniel Wagner
Chief Scientist, OET
- Dr. Leonardo Macelloni
USM
- Dr. Brian Calder
CCOM Associate Director, UNH
- Andy Bowen
DSL Director, WHOI
- Dr. Aurora Elmore
NOAA Ocean Exploration
- Dr. Rachel Medley
NOAA Ocean Exploration
- Dr. Mashkoor Malik
NOAA Ocean Exploration
- Kristen Crosset
NOAA Ocean Exploration

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From the Director

On the backdrop of continued productivity in ocean exploration,

the OECl saw many of our developmental vehicle systems, approaches, and even educational programs move from prototype to operational status in Year 3. These advancements provided real gains in operational efficiency and enhancements to the collection of ocean exploration data that the OECl and NOAA (especially NOAA Ocean Exploration) will benefit from for years to come. Examples of this include the testing and validation of the UNH DriX uncrewed surface vehicle (USV) that had its first deployments in Year 3. By the end this year, DriX was a key contributor to OECl ocean exploration data collection and a force-multiplier for multi-vehicle operations. It is important to recognize that this process was made possible through a great deal of hard work, knowledge, collaboration, and experience by many of the OECl partners and by the opportunities for at-sea operations provided by OET's E/V *Nautilus* and with support from NOAA Ocean Exploration. The ultimate realization of the power of this collaboration was demonstrated by the OECl Tech Challenge cruise that saw the UNH DriX USV, WHOI's Mesobot autonomous underwater vehicle and NUI hybrid remotely operated vehicle, all operating simultaneously while *Nautilus* conducted operations some distance away. This demonstration provided a glimpse of the future of ocean exploration where the entire water column can be explored while support vessels conduct simultaneous operations.

Similar advancements occurred across the OECl activities in Year 3. From the development of automated eDNA sampling devices to novel algorithms for processing bathymetric data, OECl continues to push the frontiers of ocean exploration. This effort also includes engaging new ocean explorers that we hope will contribute to a well-trained and diverse blue economy workforce. Our Tuskegee University Internship program, led by USM, and our Bridge to Ocean Exploration program, led by URI, are both aiming opportunities at groups that are underrepresented in ocean science and don't have routine access to the exciting career opportunities in the blue economy. Leveraging the tremendous expertise within the OECl and incredible sea-going opportunities allows us to put these students in optimal positions to explore their futures.



MARLEY PARKER

Successes in Year 3 for the OECl reflect the strong relationship between the institute partners and NOAA Ocean Exploration. Throughout Year 3 and beyond, we are seeking to amplify the power of partnership. One example of a new partnership is the testing of Sailandrone *Surveyor*, a large, long-range USV that is capable of seafloor mapping in remote areas. *Surveyor* is currently operating in the Aleutian Arc, collecting data in partnership with a consortium, including NOAA's Coast Survey (OCS), Ocean Exploration, Deep Sea Coral Research and Technology Program (DSCRTP), Research (OAR), along with BOEM, NOPP, and USGS. The OECl is also collaborating with NOAA's project teams working to restore mesophotic and deep benthic communities (MDBC) injured by the Deepwater Horizon oil spill in the Gulf of Mexico. More partnerships are on the horizon, which will bring new expertise to the OECl, create new technological and operational challenges, and enable OECl's advancements to more rapidly spread throughout the ocean science community.

As always, thank you for your ongoing interest and support.

With best regards,
Adam Soule, Professor of Oceanography, URI, and
Executive Director, Ocean Exploration Cooperative Institute

Year 3 Expeditions

U.S. West Coast

Santa Barbara Basin and West Coast EEZ Mapping (NA127)

OET and partners conducted a two-day expedition exploring oxygen minimum zones off the coast of southern California, then performed seven days of seafloor mapping within the traditional and modern lands and waters of the Tongva, Kizh, and Chumash peoples. The expedition collected 4,101 km² of seafloor bathymetry data and 99 samples. It also conducted eight ROV dives.

Cascadia Margin Seep Exploration (NA128)

This expedition explored the Cascadia Margin, a geologically active subduction zone located offshore of Washington, Oregon, and northern California. 11 ROV dives focused on several previously unexplored regions along the margin and collected samples at methane seep sites along the continental shelf.

West Coast EEZ Mapping (NA130)

OET and partners conducted an expedition filling mapping gaps along the U.S. West Coast in support of priorities identified by the Expanding Pacific Research and Exploration of Submerged Systems (EXPRESS), a partnership between NOAA, BOEM, USGS, MBARI, and the University of Southern California Sea Grant.

Technology Demonstration (NA131)

This expedition tested two autonomous vehicles from WHOI—the hybrid remotely-operated vehicle (HROV) Nereid Under Ice (NUI) and the HROV Mesobot in the Santa Monica Basin. Nine deployments of NUI, three deployments



of Mesobot, and three deployments of ROV Argus were conducted. Mesobot operations focused on collection of eDNA using its new *in situ* multisampler. NUI operations focused on demonstrating HROV behaviors, including use of ROV Argus as a communications link via optical modem.

Mapping to Hawaii (NA132)

EV *Nautilus* conducted a 10-day mapping expedition during the ship's transit. Beginning in California and ending in Hawaii, the expedition mapped 25,111 km² of seafloor, of which 6,542 km² lie within the U.S. EEZ.

Gulf of Mexico and Puerto Rico

PS21_19 and PS22_14

USM deployed the Eagle Ray AUV in search of tanker SS *Norlindo*—the first WWII casualty of Germany's U-boat campaign in the Gulf of Mexico. The *Norlindo* has yet to be found. However, newly-collected magnetometer data have shown the presence of anomalies.

Drop Camera (EX22-03)

WHOI provided technical expertise, imaging equipment for this cruise off the coast of Puerto Rico aboard *Okeanos Explorer*. The primary objectives were to assess the condition of the ship's CTD and over-board system to inform recommendations for ideal platform capabilities that support multidisciplinary wired-system operation; and integrate and perform WHOI-MISO OIS and



GoPro camera operations. Ten drop-cam lowerings were conducted between depths of 250 to 1,600 meters.

Mid-Pacific Ocean

Liliuokalani Ridge Seamounts (NA133)

This expedition mapped the Lili'uokalani Seamounts, located in and around the expansion area of the Papahānaumokuākea Marine National Monument (PMNM). This was the first-ever mapping survey of the remote seamount chain. Prior to the cruise, there was little known bathymetry in this region. Over the course of this 20-day expedition, *E/V Nautilus* mapped 32,980 km² of seafloor, of which 27,503 km² are in the U.S. EEZ.

South Wentworth and Don Quixote (NA134)

Expedition NA 134 explored the deep-water seafloor areas of the Voyager Seamounts located in and around the southern expansion area of the PMNM. Using *E/V Nautilus*' dual-body ROV system, this expedition completed 13 ROV dives. The expedition also included mapping operations covering over 21,328 km² of the seafloor, of which 18,817 km² are within the U.S. EEZ.

Chautauqua Seamounts (NA135)

E/V Nautilus explored the deep-water geology and biology of an unnamed seamount chain located approximately 240 kilometers west of Kauai Island in the U.S. EEZ of the Central Pacific. The objectives were to fill bathymetric gaps, identify the distribution and abundance of deep-sea benthic fauna, and evaluate the extent and conditions of ironmanganese crust formation on seafloor rocks.

Shakedown Cruise (NA136)

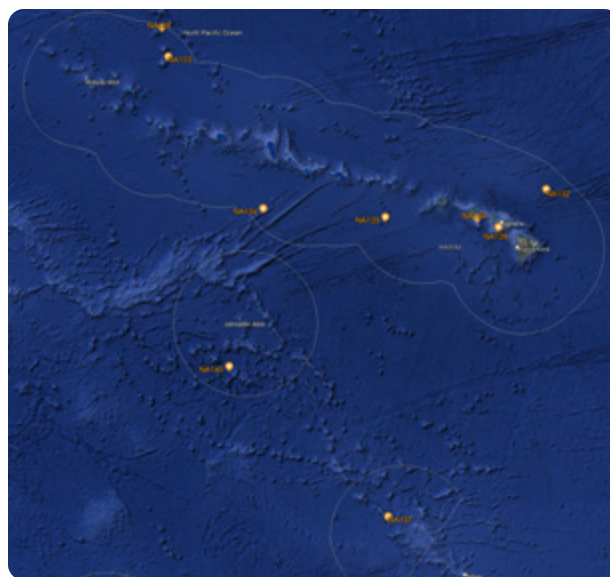
Ocean Exploration Trust and OECI partners from UNH and URI conducted a shakedown expedition aboard *E/V Nautilus* in the main Hawaiian islands to complete a series of engineering tests in preparation for the 2022 field season.

Kingman/Palmyra (NA137)

E/V Nautilus conducted an expedition to explore deep seafloor areas in the Kingman and Palmyra unit of the Pacific Remote Islands Marine National Monument (PRIMNM). Using *E/V Nautilus*' dual-body ROV system, this expedition completed eight ROV dives at depths ranging from 659 to 3,771 meters. During these dives, 80 biological, 37 geological, and 24 eDNA water samples were collected.

Lu'uaeahikiiekumu—Ancient Seamounts of Lili'uokalani Ridge (NA138)

This expedition explored areas of the Lili'uokalani Ridge within and around the PMNM. Using *E/V Nautilus*' dual-body ROV system a significant discovery of the expedition was the observation of a “yellow brick road” at a depth of 1,029 meters near the summit of Nootka Seamount and



inside PMNM. Its resemblance to a human-made brick wall, resulted in the story being picked up by numerous media outlets, including the release of over 290 news stories and over 2.7 million views of the highlight video.

Multi-vehicle Technology Challenge (NA139)

This expedition south of Oahu, west of Lanai, and west of Maui, brought together OECI partners from UNH with their USV DriX, as well as WHOI's AUV Mesobot and hybrid vehicle NUI. The team conducted 11 AUV Mesobot deployments, nine DriX deployments, and nine NUI deployments. They demonstrated communications between the three vehicles as they were simultaneously deployed. The vehicles were re-tasked based on information gained from a partner vehicle, and teleoperations with operators back on shore. In addition to technology demonstrations, the expedition included mapping operations of 79 km² of bathymetry data.

Deep Seamount Biodiversity of Johnston Atoll (NA140)

E/V Nautilus mapped seafloor areas in the Johnston Unit of PRIMNM. Using mapping sonars, the expedition mapped 35,724 km², of which 30,266 km² are within the U.S. EEZ. In addition to mapping data, the expedition also included deployment of six Spotter open-ocean buoys during transits through international waters between Honolulu and the Johnston Unit. These solarpowered, free-floating buoys collect continuous data on surface waves, winds, currents, and sea surface temperature, and transmit their data via satellite for public access.

Technology

A primary objective is to develop and deploy new technologies for ocean exploration.

In Year 3, the OECI focused on increasing the capability of individual exploration tools while developing new ways to use them collaboratively.


The OECI led two NOAA-sponsored expeditions aboard *E/V Nautilus* that were dedicated to testing the most promising vehicles and strategies.

The first OECI expedition of Year 3 was a demonstration of existing autonomous systems operated by WHOI and a ROV from OET over the course of seven days in September 2021. This was the first tech-focused expedition for the OECI due to COVID-related delays in Year 1 and 2. Mobilized onboard *E/V Nautilus* were WHOI's midwater-exploring AUV, Mesobot, and a hybrid ROV, NUI. These two systems, both capable of operating as AUVs, were complemented by a digital video plankton recorder and OET's ROV, Argus. Seven days was an extremely brief expedition with systems this complicated, but the team successfully paired multiple subsea systems together, showcasing the added value of collaboration between autonomous systems.

NUI was deployed over a methane seep site in autonomous mode, which, normally, would limit the capabilities of the vehicle to traditional survey/reconnaissance activities. Instead of accepting these limitations, the team deployed ROV Argus and, through a WHOI-developed optical modem, the team was able to execute ROV functions from NUI (like collecting a sediment sample) without the vehicle being physically connected to the ship. The key enabler was the increased bandwidth of the optical modem, which, once the sampling was completed, allowed NUI to return to typical AUV operations of making high-resolution multibeam scans. This flexibility is new to ocean exploration and a testament to the innovative thinking within the OECI membership.

Robotic exploration vehicles, from left to right: Nereid Under Ice, Mesobot and DriX. Far right, Molly Curran prepares a vehicle for deployment.





Building on the success of the technology demonstration in 2021, the team mobilized in Hawai'i in May, 2022. In addition to NUI and Mesobot, the team from UNH mobilized the USV DriX onto E/V *Nautilus*. DriX was acquired by UNH through the support of NOAA Ocean Exploration via OECI and is a central component of the OECI multi-vehicle strategy. The culmination of the expedition was exploring a seamount off the coast of Maui. Over the preceding days, NUI and Mesobot had both operated in this area while paired with DriX, which acted as a communications link with *Nautilus*. Advancing the ability to monitor and redirect an autonomous system 15 kilometers away from the ship is a significant force-multiplier for ocean exploration.

Yet, DriX is so much more than a communication relay. While monitoring either Mesobot or NUI, DriX simultaneously collected high-resolution multibeam bathymetry. In addition, data from DriX's EK80 bio-acoustic sonar also revealed the distribution of marine life in the area surrounding the seamount.

The successful mission with two vehicles led the team to devise an exploration plan around this seamount using all three uncrewed systems simultaneously. The value of such a complicated multi-vehicle scenario became clear as NUI identified a change in the density of seawater near the base of the seamount. NUI immediately directed Mesobot to collect midwater readings over the same location and further confirm anomalous readings.

The ability to make instantaneous shifts in a mission to further understand an anomaly is a new and exciting technique for exploration. The OECI has now shown that this sort of investigation shouldn't rely on data from a single source. Rather, it should utilize multiple sources at the same time throughout the water column. Following this success, the OECI is looking to further develop the concept of 'verified directed sampling' and to continue development of new vehicles and tools necessary to make multi-vehicle operations routine.

Every new idea is a step in the right direction. Small ideas build on each other, and can spark another from a team member, eventually developing into something great.

*— Molly Curran
NUI Team Lead, Woods Hole
Oceanographic Institution*

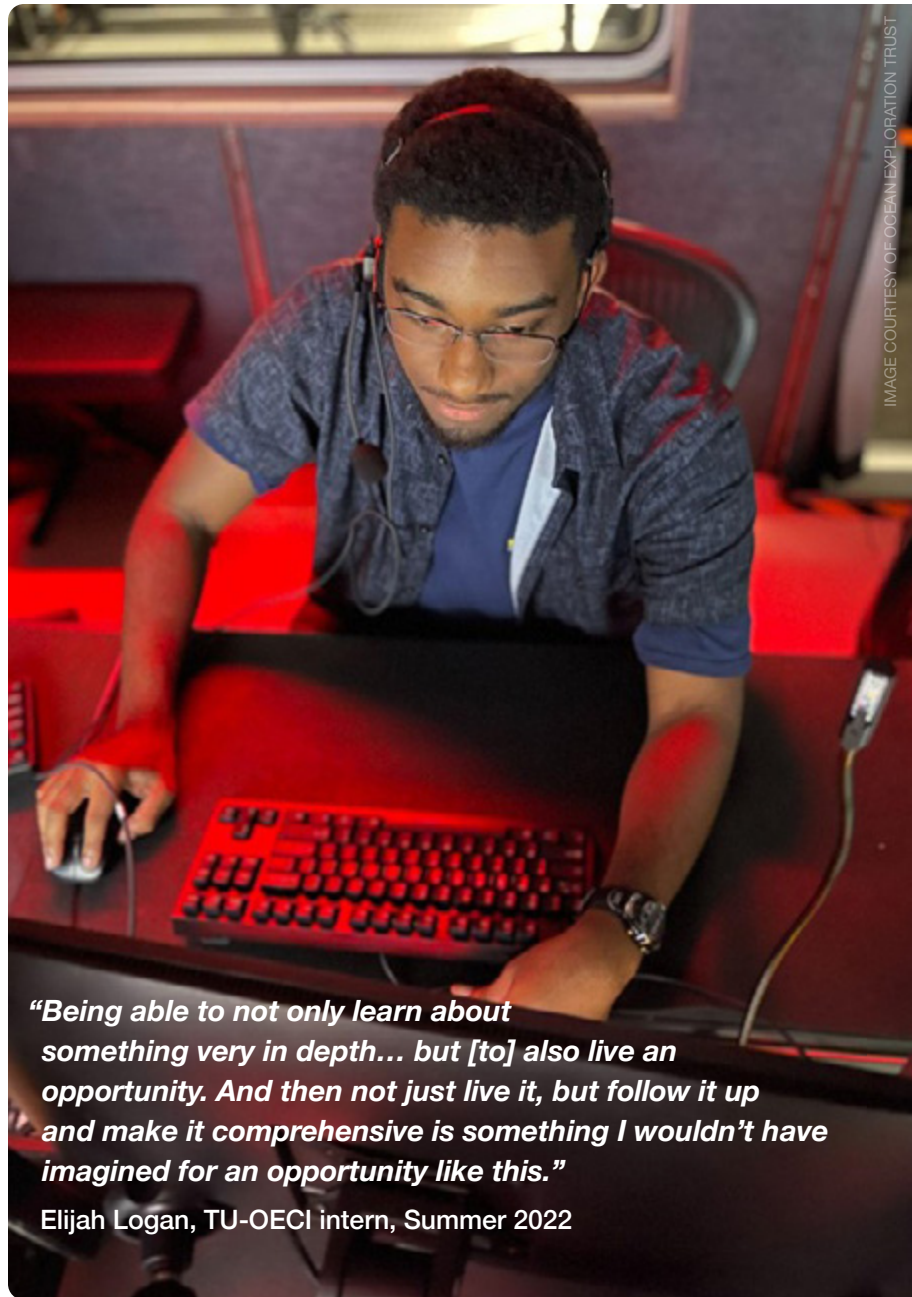


PHOTOS COURTESY OF OCEAN EXPLORATION TRUST

Engagement and Education

The OECI is committed to engaging with and training the next generation of ocean explorers.

In Year 3, the OECI funded and initiated training programs that targeted underrepresented groups in oceanography with partners including Tuskegee University and New England Institute of Technology. These programs, also funded by NOAA OER, help students explore the range of pathways into the blue economy workforce, and supplement existing OECI partner-led programs that reach thousands of students and educators across the country.



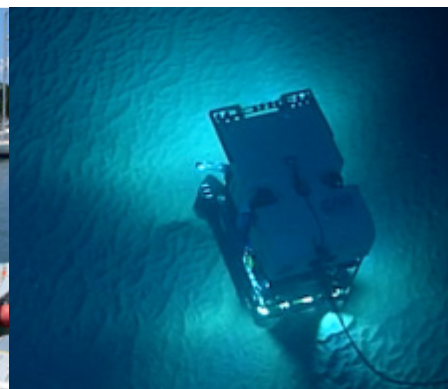
“Being able to not only learn about something very in depth... but [to] also live an opportunity. And then not just live it, but follow it up and make it comprehensive is something I wouldn’t have imagined for an opportunity like this.”

Elijah Logan, TU-OECI intern, Summer 2022

Left, Tuskegee University students joined labs across the OECI for summer internships including characterizing eDNA in WHOI’s Govindrajan lab.

Center, Deep-Sea Dialogues enabled K-12 educators to join virtual spaces for professional development to make deep-sea science accessible to their students.

Right, Tuskegee University interns provided peer-to-peer support virtually over the summer, and met in person to share the results of their summer research.



With OET and URI

We are extremely proud of the broad reach achieved by the OET's engagement and communications efforts, which introduced millions of learners to ocean exploration and STEAM career activities in meaningful ways. OET's live streams routinely attract millions of views during their field season, and these exploration activities can capture the imagination of learners of all ages.

This was evident in the April 2022 discovery of the “yellow brick road”, an unusual geological formation on the summit of Nootka Seamount in the Papahānaumokuākea Marine National Monument, during the Lu'uāeaahikiikekumu E/V Nautilus expedition. Through OET's efforts, this discovery resulted in more than 270 news stories across 26 countries and attracted more than 2.8 million views of the associated video highlight. In addition, embedded educators and science communicators engage hundreds of K-12 classrooms and community events each exploration season through ship-to-shore live interactions.

The OECl's education and outreach efforts also included work supporting NOAA Ocean Exploration's Deep Sea Dialogues (DSD) video production and virtual professional development (PD) program, produced in collaboration with URI's Inner Space Center. To date, over 1,500 K-12 educators from across the U.S. and its associated territories have been engaged in DSD programming.

In the Fall of 2021, over 240 educators participated in virtual PD programming on bioluminescence. In the Spring of 2022, 235 educators registered to participate virtually in a PD program on deep sea corals. YouTube views after the events were two to three times greater than live event participation—an unanticipated bonus to this year's programming.

The video pieces and PD events continued to be received with enthusiasm and positive reactions from educators, who amplify the program's impacts by sharing them with an average of 100 students per educator per year. Many teachers also show the online archived DSD videos.



With OECl and TU

The Bridge to Ocean Exploration program (B2OE) seeks to develop pathways into the blue economy workforce for students acquiring technical skills. The program is designed to accommodate students whose economic, family, work, and/or education responsibilities preclude participation in typical, 8–10 week summer internship programs.

From December 2021 through May 2022, the OECl supported four students from the New England Institute of Technology (NEIT) for part-time work in areas ranging from the development of 3-D models and animations of vehicle technology to the implementation of machine learning algorithms to analyze ROV video data. The students were able to gain valuable science communication experience and share the results of their work at the NOAA/OECl event attended by NOAA Administrator Dr. Rick Spinrad and Pennsylvania congressman Matt Cartwright.

The program concluded with a virtual Blue Economy Career Awareness fair attended by representatives from research, commercial fishing, ports, offshore wind, and defense sectors to share their insights on potential career pathways. Participation in the fair included Tuskegee University Ocean Club members, NOAA OECl interns, and more.

The Tuskegee University (TU) Ocean Exploration Internship program matched TU undergraduate students with mentors from OECl partner institutions for intensive field- and laboratory-based experiences in a paid, 10-week placement. This program is built upon a strong foundation through the TU Ocean Exploration Club that provides a venue for interested students to engage with ocean explorers and researchers and learn about opportunities in which they can participate in the internship program and discover blue economy jobs.

In Year 3, the OECl placed five interns at OECl partners (one at URI-GSO, UNH, and OET, and two at WHOI) where the students directly contributed to OECl research efforts and gained practical experience in everything from genetic analyses of eDNA to the collection and processing of seafloor mapping data. The program recognizes the challenges of placing minority-identity students into predominantly white ocean research institutions and engages with students weekly and provides peer-to-peer support for the challenges they may face.

The interns completed their summer at an in-person event on the Mississippi Gulf Coast—exploring careers, touring facilities, and building connections with marine scientists at all stages and disciplines. The program officially concluded with a hybrid research symposium with more than 60 participants. The OECl is very pleased that the students had great experiences and that some are now considering pursuing advanced degrees and/or careers in ocean science.

Partnerships

It's a big ocean, and there is much left to explore.

For that reason, NOAA and the OECl have partnered to gather as much experience, creativity, and knowledge, along with a wide array of tools and resources, to accelerate ocean exploration. However, even more partnerships are needed in order to meet the challenge of exploring the U.S. EEZ. In Year 3, the OECl has developed collaborations with other NOAA line offices, federal agencies, commercial, and educational partners. These partnerships are advancing ocean exploration, bringing new innovations to the ocean exploration enterprise, and helping to propagate OECl innovation and expertise to the broader community.



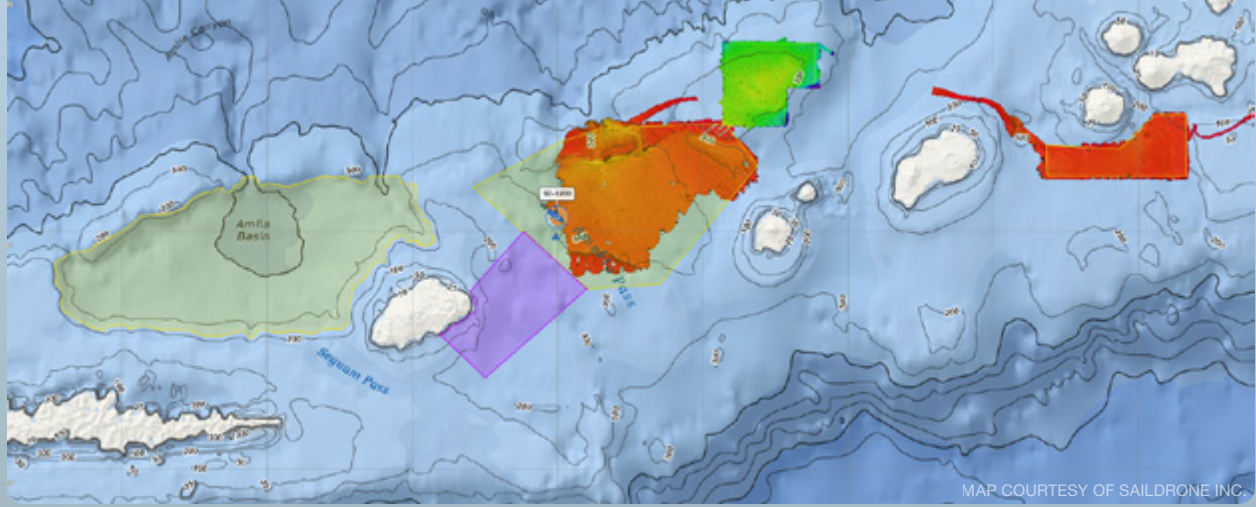
Native Hawaiian Partnership

OECl partnerships extend well beyond innovations in technology. A prime example of this is Ocean Exploration Trust's partnership with representatives of the Papahānaumokuākea Marine National Monument's (PMNM) Cultural Working Group facilitated by the Office of Hawaiian Affairs. This collaboration ensures that all OECl research in the monument is conducted with respect to native Hawaiian culture, traditions, and worldview. As a result, all OECl expeditions within the PMNM in 2021 and 2022 were gifted Hawaiian language—'Ōlelo Hawai'i—names. The names reflect the significance of these areas to Hawaiian peoples and serve to remind those conducting exploration activities of their responsibility to a specific place.

For example, Lu'uaeaahikiiekumu, which represents the journey to and work in the foundation of the ocean/islands was the name for one expedition. In addition to the naming, OET and the OECl provided paid at-sea leadership positions for Hawaiian cultural liaisons, who participated in research expeditions, leading traditional Hawaiian protocol, including "mele," "oli," "pule," and the offering of "ho'okupu." Liaisons also established appropriate actions, practices, and behaviors to acknowledge the significance of the space, seek permission, and set intentions for seeking knowledge through exploration activities. This partnership also guided the development of culturally grounded outreach and engagement activities, delivered in 'Ōlelo Hawai'i, with communities and schools serving youth in Hawaiian language revitalization programs.

The OECl strengthened its understanding that much of what we discover in service to federal priorities, the scientific community, and the public, exists in some form within the cultural knowledge of Indigenous communities.

Top: Native Hawaiian science communication fellows, data, and video interns took an active role in the OECl's exploration within the PMNM.



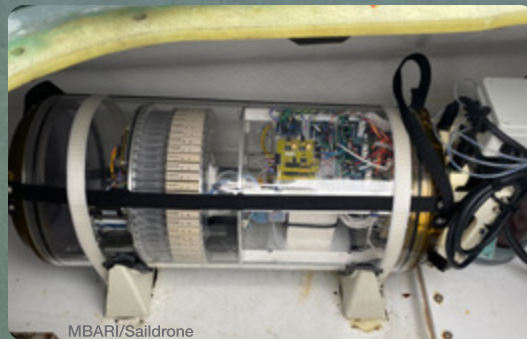
MAP COURTESY OF SAILDRONE INC.

Multi-Agency Saildrone Partnership

The OECI is working with NOAA Ocean Exploration, Office of Coast Survey, Office of Ocean and Atmospheric Research, and the Deep Sea Coral Research and Technology Program, as well as the Bureau of Ocean Energy Management (BOEM), the U.S. Geological Survey (USGS), and the Monterey Bay Aquarium Research Institute (MBARI) on a collaboration with Saildrone to apply their development of the new Saildrone *Surveyor* vehicle to ocean exploration in the Aleutian Arc. The Aleutian region remains one of the least explored portions of the U.S. EEZ given its vast area and remoteness relative to the continental U.S., where most oceanographic facilities are located. However, the promise of discovery within the Aleutian region is exceptionally high with the potential to identify new chemosynthetic ecosystems driven by hydrothermal circulation powered by Aleutian volcanism and methane seepage that has been found at other convergent margins. In addition, new deep-water coral and sponge habitats, geohazards and unique abyssal and hadal environments drive the need for exploration of this region.

Surveyor is a new Saildrone platform, and with increased size (72 feet) and endurance, it provides a promising tool for conducting initial exploration of remote regions. Following its successful uncrewed

mission from its homeport in central California to Honolulu last year, the Saildrone team is excited to see *Surveyor* put to work in the Aleutians. “Working with NOAA and the OECI allows us to test the capabilities of *Surveyor*, including its endurance, the use of multiple sonar systems for a range of surveying targets and the integration of the MBARI supplied eDNA sampling system.” (*inset*) says Brian Connon, Saildrone’s vice president of ocean mapping.

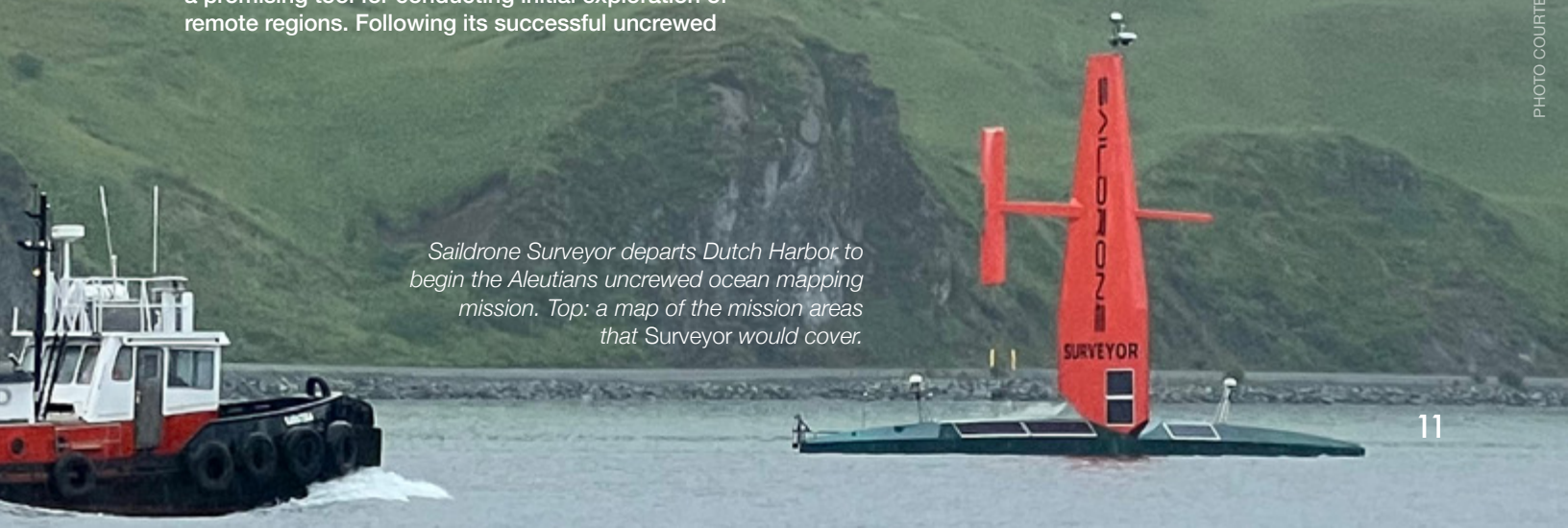


MBARI/Saildrone

With the OECI’s leadership, the Saildrone mission is currently underway and real-time updates of mapping coverage and environmental data are streaming to shore. “We are incredibly excited to work with all of the partners on this project,” said Mark Mueller, benthic ecologist at BOEM.

“Innovative survey platforms like *Surveyor* address a real need for highly capable uncrewed vehicles that can cost effectively gather critical ocean information in the most remote regions of the U.S. EEZ. BOEM and our federal partners need that information to understand natural resources and protect sensitive habitats. This project gives us a hopeful glimpse into a future where cutting edge technologies become commonplace in ocean exploration and characterization work.”

Saildrone Surveyor departs Dutch Harbor to begin the Aleutians uncrewed ocean mapping mission. Top: a map of the mission areas that *Surveyor* would cover.



259 
DAYS AT SEA

17 
EXPEDITIONS

193,405 sqKM

Mapped
(Area about the size of all
of New England - ME MA
NH VT RI CT)

148,233 sqKM

Mapped within the US EEZ
(Size of Florida)

120
DEPLOYMENTS

 **973**
Samples with over
1000 sub samples

64
ROV

56
UxS

249 
eDNA
samples

By the Numbers



OEI Publications

Ocean Exploration Data

Expeditions in Year 3 collected terabytes of meaningful exploration data and dramatically increased knowledge of unexplored ocean regions. As results are processed and published, the supporting data will be made available to the general public, interested scientists, and inquisitive students.

All data and samples from expeditions conducted aboard *EV Nautilus* are now available at these organizations:



Rolling Deck to Repository
(underway data)



NOAA National Center for Environmental Information



Marine Geoscience Data System
(vehicle and geoscience data)



Marine Geological Samples Lab (Geological Samples)



YouTube
(underwater video)



Museum of Comparative Zoology (Biological Samples)