



Ocean Exploration

DRIVEN FORWARD THROUGH PARTNERSHIPS

A healthy ocean is critical to a healthy planet, yet significant gaps exist in our basic understanding of deep waters, the seafloor, and the resources they hold.

Ocean exploration is critical to sustaining and accelerating the economy, health, and security of our planet and providing information about our ocean systems. Even today, the vast majority of Earth’s ocean remains unexplored and unmapped by modern standard technology, high-resolution multibeam sonar.

With the enormity of work to accomplish, ocean exploration—whether conducted by a government agency, a foundation, a non-profit organization, academic institutions, or the private sector—is inherently partnership driven. The NOAA Office of Ocean Exploration and Research (OER) Ship *Okeanos Explorer*, Ocean Exploration Trust’s (OET) E/V *Nautilus* and Schmidt Ocean Institute’s (SOI) R/V *Falkor* use a similar overall strategy for exploring Earth’s ocean. While their specific exploration activities vary from ship to ship and mission to mission, much of their efforts are executed in partnership, often with the work of one expedition building on the work of another over time.

The goal of these ocean exploration efforts is to develop baseline information about the biological, geological, and water chemistry features of unexplored areas to provide a foundation

for future research and understanding of the system functions. This information includes: high resolution maps of the seafloor, surveys of the water column, physical sampling to characterize the composition and biodiversity of habitats, and high definition video of biological, geological and archaeological features in the exploration area.

The ocean exploration community works together to identify priority areas of study by seeking input from researchers and science organizations. The strength in the collaboration of NOAA OER, SOI and OET is in using many platforms to address the expanse of unexplored regions and questions that exist in understanding our ocean landscape and its dynamics. Results from all ships spur new questions and provide fresh perspective driving further exploration of phenomena in new locations.

Over the past several years, these three vessels have traveled throughout the Pacific and Atlantic Oceans, and the Gulf of Mexico making exceptional discoveries.

WORKING TOGETHER

The best discoveries and research findings are achieved when groups work together towards a common goal. Like other fields in today's interconnected world, ocean exploration is a highly collaborative, interdisciplinary enterprise where organizations share data and results to leverage and expand future efforts. These three ships of exploration work closely together and frequently support and build upon one another's work in unexplored areas of our planet. A few examples are:

The Central and Western Pacific

A "campaign" approach to ocean exploration is becoming more commonplace. This approach involves cooperation by multiple vessels, exploration platforms and organizations, sharing resources to utilize the most appropriate tools to explore a region over multiple years. When exploring in the central Pacific, multibeam data and exploration reports from the *Okeanos Explorer* and the *Falkor* helped the *Nautilus* team identify priority areas still unexplored or not yet fully mapped to high resolution. Data collected in these important protected regions, such as the Mariana Trench Marine National Monument and the Phoenix Islands Protected Area continue to be used to identify future research locations. Sharing dive reports and ROV imagery expands existing knowledge, provides new understanding of Pacific-wide species occurrences and expands important insight of how seamount and vent fauna colonize and evolve.

DIVE DEEPER INTO THESE EXPEDITIONS HERE:

oceanexplorer.noaa.gov/okeanos/explorations/capstone/welcome.html

schmidtocean.org/cruise/searching-life-mariana-back-arc/

schmidtocean.org/cruise/discovering-deep-sea-corals-phoenix-islands/
<https://nautiluslive.org/expedition/2019>

Discovering Deep Sea Corals of the Phoenix Islands

In 2017, R/V *Falkor* transited to the Phoenix Islands Protected Area in the Republic of Kiribati, one of the largest and deepest UNESCO World Heritage Sites. Following initial exploration of the Western seamounts by the NOAA ship *Okeanos Explorer*, this expedition revealed eight previously unexplored Eastern seamounts and atolls. Additionally, ROV images and video revealed new observations of octopus behavior, captured one of the deepest records of mantis shrimp, and defined seamount habitat zones from the deep sea to the surface for the first time. ROV footage and samples regularly contribute to the possible discovery of new species and vastly expands our understanding of deep-sea corals and their associates.

DIVE DEEPER INTO THESE EXPEDITIONS HERE:

oceanexplorer.noaa.gov/explorations/17pipa/welcome.html

oceanexplorer.noaa.gov/okeanos/explorations/ex1703/background/pipa/welcome.html

DIVE DEEPER INTO THESE EXPEDITIONS HERE:

nautiluslive.org/cruise/na031

oceanexplorer.noaa.gov/explorations/13monterrey/welcome.html

oceanexplorer.noaa.gov/news/oeer-updates/2019/boem-virtual-museum.html

The Monterrey Wreck in the Gulf of Mexico

While exploring in the Gulf of Mexico in 2013, *Okeanos Explorer* discovered a shipwreck dubbed "the Monterrey Wreck" near Flower Garden Banks National Marine Sanctuary. Appearing from the visuals to be an undisturbed early 19th century, copper-clad, wooden sailing vessel, this wreck captured a great deal of attention from the marine archaeology community. The discovery prompted a 2014 E/V *Nautilus* expedition to return to the site to carefully document, map, video, and photograph the wreck as well as recover a small number of artifacts for conservation and analysis. During this mission, the *Nautilus* team discovered two more shipwrecks nearby of similar age leading archaeologists to theorize the ships were a convoy lost together in a late eighteenth century hurricane. The Monterrey wreck remains the deepest excavated shipwreck in U.S. waters. This exploration has since led to the Bureau of Ocean Energy Management's Virtual Archaeology Museum showcasing an interactive 3D model of the Monterrey A Shipwreck.



As all three ships continue to advance our exploration tools and expertise, innovative technologies, data, and ability to inspire exploration audiences with new ocean experiences – collectively, we will better understand, manage, and appreciate our marine environment for the benefit of the nation and the planet.

Exploring the vast unknown elements of our ocean is a massive undertaking requiring a substantial long-term cooperative effort. Many scientists work with all three vessels (along with others) as they strive to explore more of our ocean planet.

CAREER INFO

oceanexplorer.noaa.gov/edu/oceanage/welcome.html
nautiluslive.org/people
schmidtocean.org/education/careers-at-sea/



Dr. Diva Amon
Marine Biologist and Deep-sea Explorer,
Natural History Museum, London; image credit NOAA OER



Dr. Christopher Kelley
Program Biologist, Hawaii Undersea Research Laboratory,
University of Hawaii; image credit NOAA OER

Programs like NOAA OER, OET and SOI are leading the way in exploring areas of the deep seafloor and vast water column. As science is an interactive process with answers often leading to more questions, this trifecta of ships build on one another's work to advance our understanding of our ocean.

I have been privileged to lead deep water research cruises from all three ships. The data sharing and coordination that I witnessed between OER, OET, and SOI over the years has led to significant and dramatic advances in our understanding of Pacific deep water geology and biology.

some highlights include...

BIOLOGICAL DISCOVERIES



Exploring the depths of the Pacific in 2016, the expedition team encountered an **unusual octopus** that lacked the pigment cells, called chromatophores, typical of most cephalopods leading it to be referred to as Casper, like the friendly cartoon ghost. This is almost certainly an undescribed species, and at 4290 meters, this was a record depth for animals of this kind. NOAA *Okeanos Explorer* Hohonu Moana: Exploring Deep Waters off Hawai'i 2016 expedition.

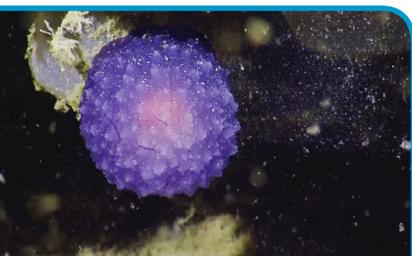
LEARN MORE ▶ <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1603/dailyupdates/dailyupdates.html#cbpi=feb27.html>



This enormous, and presumably very old, sponge was discovered at 2117 meters inside the Papahānaumokuākea Marine National Monument. Determined to be over 3.5 meters in length, 2 meters in width and 1.5 meters in height (the size of a minivan) this is now deemed the **largest sponge known**. While not much is known about the lifespan of sponges, some massive species found in shallow waters (<30 meters) are estimated to live for more than 2300 years, underscoring the need to protect this area using the highest conservation measures available.

NOAA *Okeanos Explorer* Hohonu Moana: Exploring the Deep Waters off Hawai'i 2015 Expedition.

LEARN MORE ▶ <https://oceanexplorer.noaa.gov/news/oer-updates/2016/big-sponge.html>;
<https://oceanexplorer.noaa.gov/okeanos/explorations/ex1708/dailyupdates/dailyupdates.html#cbpi=sept24.html>



Looking like a glowing purple disco ball, explorers were stumped seeing an organism near Channel Islands National Marine Sanctuary with a snail-like foot and no visible shell. Consulting with scientists ashore, the team initially believed it might be a pleurobranch sea slug. Years after the expedition, the mystery of the purple orb continues! Upon a more-detailed expert review, it is now thought the orb belongs to another **distantly related group of snails – the velutinids**. Modern techniques, including microCT scanning and RNA sequencing, are being used to describe this very likely new species of velutinid. OET E/V *Nautilus* Southern California Margin 2016 expedition.

LEARN MORE ▶ <https://nautiluslive.org/cruise/na075>; <https://nautl.us/2XkQoqg>



While exploring Davidson Seamount, an inactive volcanic undersea mountain off the coast of central California in Monterey Bay National Marine Sanctuary, explorers discovered aggregations of **over 1,000 brooding female octopuses** (*Muusoctopus robustus*)! This genus has an unusual “upside-down” brooding posture, with the underside of the arms exposed and the mantle toward the eggs, which are cemented to bare rock. This is the first time aggregations of this size have been sighted in US waters.

OET E/V *Nautilus* Monterey Bay National Marine Sanctuary 2018 expedition.

LEARN MORE ▶ <https://nautiluslive.org/cruise/na103>; <https://nautl.us/2XkQqhS>



In 2014, explorers executed the first systematic survey within the Mariana Trench, focusing on the 10,700 meters Sirena Deep, part of the United States Mariana Trench Marine National Monument. Using depth landers, among other equipment, a major goal was to assess what types of animals could be found at each depth zone. Several samples gathered were entirely new species, including **this snailfish that has since remained unfound at this depth** despite being common in the 6,000-8,000 meters range. This ethereal fish had tissue-thin fins and an eel-like tail resembling a ghost; the press later referred to the find as the “ghost fish of the deep.” SOI R/V *Falkor*, Mariana Trench 2014 Expedition.

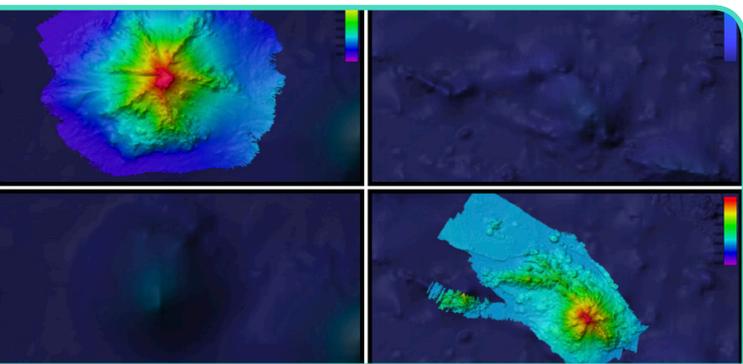
LEARN MORE ▶ <https://schmidtocean.org/cruise/exploring-the-mariana-trench/>;
<https://www.youtube.com/watch?v=U9YLFxzZvs>



In 2018, scientists from Stanford University, MBARI, Monterey Bay Aquarium, the University of Delaware, and NOAA joined their efforts aboard *Falkor* to learn what **draws white sharks to an area previously perceived as a desolate “oceanic desert”** located halfway between Hawaii and California and named the White Shark Café. Two environmentally powered Saildrones were launched to find and track tagged sharks two months ahead of *Falkor's* arrival. Using ROV *SuBastian*, the team gathered DNA samples to better understand what draws the sharks to this remote area. The new findings will help make a case for designating the Café as the first high seas World Heritage Site. SOI R/V *Falkor*, *White Shark Cafe* 2018 Expedition.

LEARN MORE ▶ <https://schmidtocean.org/cruise/voyage-white-shark-cafe/>
<https://www.youtube.com/watch?v=vyCkbaBgYNA&list=PLJGVqQI3okzZsZYBgPx5DqEYtQZLR2CfH&index=40>

GEOLOGICAL AND CHEMICAL DISCOVERIES



In 2016, Papahānaumokuākea Marine National Monument's boundaries were expanded, encompassing a series of **enigmatic seamounts** with a location and origin that don't neatly match the geological explanation of hotspot volcanism which drives the major island chain formation in Hawai'i. The *Nautilus* team explored an alternate origin hypothesis – arch volcanism – within these ten seamounts beginning with mapping their rugged complexity for the first time, and then cataloguing highly diverse sponge and coral communities. The expedition was capped off with a surprise sighting of a **gulper eel** delighting the onboard team and viewers at home!

OET E/V *Nautilus* Cascadia Margin & Washington Mapping 2018 Expedition.

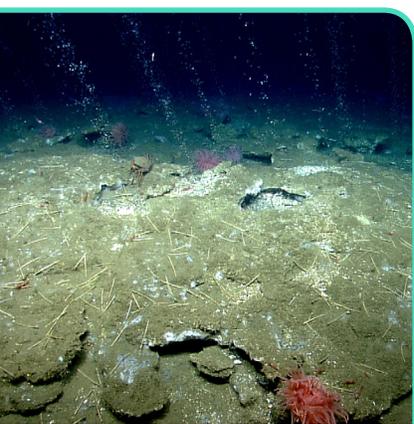


LEARN MORE ▶ <https://nautiluslive.org/cruise/na101>; <https://nautl.us/2XoAoDC>



Autonomous and interactive seafloor mapping systems enabled an exploration team to discover a new hydrothermal vent and multiple new deep-sea organisms. The new vent, JaichMatt, was identified using high resolution technology that created a holistic view of the seafloor. JaichMatt translates to "liquid metal" in one of the indigenous native languages to the Baja Peninsula. The name references the **reflective hydrothermal fluid and seawater contact (mirror lakes)** that was found pooled along the roof of a large cavern in the hydrothermal mound. Collected volcanic rocks confirmed the continental rifting that formed the Gulf of California has transitioned to seafloor spreading and the creation of new oceanic crust. SOI R/V *Falkor* Investigation of a New Hydrothermal Vent Field 2018 Expedition.

LEARN MORE ▶ <https://schmidtocean.org/cruise/interdisciplinary-investigation-of-new-hydrothermal-vent-field/>



Unlike hydrothermal vents, which occur at the edges of tectonic plates where new seafloor is formed in fiery processes, cold seeps lie within plates and leak fluids and gases that are at or close to ambient deep-sea water temperatures. Like hydrothermal vents, cold seeps often host special biological communities that use chemical, not photosynthetic, processes to derive their energy.

In 2012, **approximately 50 potential distinct seafloor gas seeps were identified by using multibeam sonar** along the Eastern U.S. continental margin. Since these initial discoveries, a substantial number of seep locations have been identified in water column mapping data and seeps are now known to exist throughout almost all depth ranges and in all of the global oceans. NOAA *Okeanos Explorer* Northeast U.S. Canyons 2013 Expedition.

LEARN MORE ▶ <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/logs/july12/july12.html>
<https://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/logs/photolog/welcome.html#cbpi=/okeanos/explorations/ex1304/dailyupdates/media/video/dive4/dive4.html>

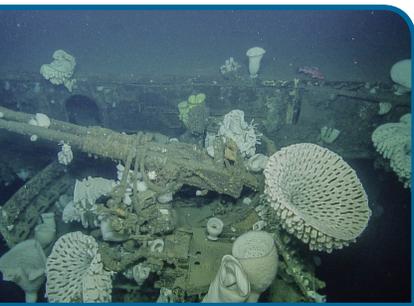


This **incredible active hydrothermal vent** was imaged for the first time in 2016. It was 30 meters high and gushing high-temperature fluid full of metal particulates. This vent was home to many different species, including shrimp, squat lobsters, crabs, limpets, mussels, and snails.

NOAA *Okeanos Explorer* Deepwater Exploration of the Marianas 2016.

LEARN MORE ▶ <http://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/may12/welcome.html>
<https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/dailyupdates/dailyupdates.html#cbpi=may2.html>

MARITIME HERITAGE *DISCOVERIES*



There is more undiscovered history in the ocean than in all the world's museums combined. Working off of an industry survey tip, the *Nautilus* Corps of Exploration launched an expedition within Greater Farallones National Marine Sanctuary to locate and survey the hulking 190m **USS Independence, a World War II aircraft carrier scuttled in the 1950s**. This ship, once the target of Bikini Atoll atomic test blasts, is now the home to a vibrant sponge reef and deep sea habitat.

OET E/V *Nautilus*, Greater Farallones National Marine Sanctuary 2016 Expedition.

LEARN MORE ▶ <https://nautl.us/2YoLmFz>



During World War II, many aircraft were lost in the Pacific Ocean in the vicinity of Tinian and Saipan. A B-29 Superfortress, **one of the largest aircraft flown by the United States in WWII**, came to rest on the sea floor upside down with the landing gear and three of the radial engines still attached. The identity of the plane remains unknown.

NOAA *Okeanos Explorer* 2016 Deepwater Exploration of the Marianas 2016 Expedition.

LEARN MORE ▶ <https://oceanexplorer.noaa.gov/okeanos/explorations/ex1605/logs/jul9/welcome.html>

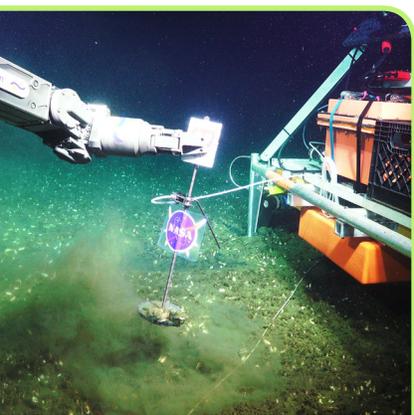
OCEAN/SPACE *CONNECTIONS*



Research in the deep sea may assist in **the search for extraterrestrial life!** Working in partnership with NASA and NOAA, SUBSEA (Systematic Underwater Biogeochemical Science and Exploration Analog) scientists study deep sea hydrothermal vent systems as analogs to other ocean world environments in the solar system. Recently, the SUBSEA team discovered a new vent field on Gorda Ridge off the northwest U.S., emitting clear fluids at temperatures around 300°C, naming it Apollo Vent Field in honor of the 50th anniversary of the moon landing.

OET E/V *Nautilus*, Gorda Ridge expedition in 2019.

LEARN MORE ▶ <https://nautl.us/2WWAIOc>



When NASA conducts planetary expeditions, they operate the vehicles through remote control – a person on Earth sends commands to the vehicle in space. However, even when using communications operating at the speed of light, there is a long gap in time between the transmission of the command and the robot's reception of it. This can cause problems when the vehicle is working in hazardous environments. The longer the distance, the longer the latency, which makes obtaining needed information a challenge. A team of engineers and scientists are working to improve this issue using robotic systems to find and map rocky outcrops and biological hotspots without being directed where to search. Rapid, AI-driven data analysis more than **doubled the utilization of robots** during this expedition and allowed the researchers to survey 28,490 square kilometers of ocean within only nine days.

SOI R/V *Falkor* New Approaches to Autonomous Exploration at the Costa Rican Shelf Break 2018 Expedition.

LEARN MORE ▶ <https://schmidtocean.org/cruise/new-approaches-autonomous-exploration-crsb/>

PARTICIPATING ORGANIZATIONS



NOAA's Office of Ocean Exploration and Research

NOAA's Office of Ocean Exploration and Research (OER) is the only federal organization currently dedicated to exploring our unknown ocean. NOAA OER works with scientists to explore uncharted areas of our ocean, to design, test, and implement new deep-sea technologies, and to bring the wonders of ocean exploration to decision-makers, educators, students, and the general public. <https://oceanexplorer.noaa.gov>

PROFESSIONAL DEVELOPMENT

OER offers free, onsite, full-day educator professional development opportunities throughout the country. Content includes the importance of ocean exploration, advanced technological capabilities used to explore the deep and open ocean, recent discoveries, and standards-based, hands-on activities and online resources for use in classroom instruction. https://oceanexplorer.noaa.gov/edu/development/onsite_development.html

LESSONS/ACTIVITIES

OER provides hundreds of standards-based lessons developed by ocean explorers and educators targeting grades 5-12. <https://oceanexplorer.noaa.gov/edu/lessonplans/lessonplans.html>

All expeditions are archived with associated Expedition Education Modules designed as education packages to share the excitement of daily at-sea discoveries and the science behind NOAA's major ocean exploration expeditions with students. <https://oceanexplorer.noaa.gov/edu/modules/welcome.html>

LIVE ONLINE

Educators, students, and the general public can watch the NOAA Ship *Okeanos Explorer* expeditions live via: <https://oceanexplorer.noaa.gov/okeanos/media/exstream/exstream.html>

Expedition Webinars for educators introduce the science behind upcoming expeditions and associated education resources as well as summarize the most fascinating discoveries from the previous exploration season. <https://oceanexplorer.noaa.gov/livestreams/welcome.html>

EXPLORE MORE

<https://oceanexplorer.noaa.gov/image-gallery>
https://oceanexplorer.noaa.gov/video_playlist.html
www.youtube.com/oceanexplorergov
www.facebook.com/oceanexplorationeducation



Ocean Exploration and Research

Ocean Exploration Trust

Ocean Exploration Trust (OET) is a 501(c)(3) nonprofit founded by Dr. Robert Ballard to explore the ocean seeking out new discoveries, pushing the boundaries of technological innovation, and using the excitement of discovery to inspire and engage the next generation of explorers and STEM professionals. The international program is launched from aboard the Exploration Vessel *Nautilus*, offering live 24-hour exploration to participants on shore and the public via live video, audio, and data feeds. www.nautiluslive.org

LESSONS & ACTIVITIES

Register for FREE access to over 90 STEM lessons and activities. STEM Learning Modules are hands-on, inquiry-driven, standards-aligned educational companions to E/V *Nautilus* expeditions. The Digital Resource Library supports educators with resources like warm-up activities, real-world datasets, website watch-guides, and themed video playlists for simple ways to bring exploration into the classroom. www.nautiluslive.org/education

EDUCATOR FELLOWSHIPS

OET's Science Communication Fellowship immerses formal and informal educators, writers, and communicators in the Corps of Exploration during expeditions at sea and empowers them to bring ocean exploration to global audiences. www.nautiluslive.org/education

LIVE ONLINE

Participate in E/V *Nautilus* expeditions and submit live questions and answers to our explorers onboard at www.nautiluslive.org.

Watch archived remotely operated vehicle dives at <https://youtube.com/evnautilus>.

Capabilities aboard E/V *Nautilus* enable students to engage in a unique two-way, live dialogue through Google Hangouts Meet with scientists, engineers, and educators of the Corps of Exploration. 30-minute live question and answer sessions cover the latest events of an expedition and are driven by student questions. Contact_education@oet.org for more information.

PROFESSIONAL DEVELOPMENT

OET provides educator professional development opportunities throughout the country as supported by program sponsors. Sign up for OET's newsletter to keep up to date with events in your area. www.nautiluslive.org

EXPLORE MORE

<https://nautiluslive.org/expedition-map>
www.nautiluslive.org/photos-videos
<http://nautiluslive.org/blog>



Schmidt Ocean Institute

Schmidt Ocean Institute (SOI) is a 501(c)(3) private nonprofit foundation established by Eric and Wendy Schmidt to advance oceanographic research, discovery, and knowledge, and catalyze sharing of information about the ocean. SOI explores the global ocean, providing state of the art operational, technological, and informational support to pioneering marine scientists, engineers, and students. <https://schmidtocean.org>

LESSONS/ACTIVITIES

The R/V *Falkor* inspired three lessons based on authentic research conducted onboard using data that have been collected by scientists at sea. Lessons are aligned to the Next Generation Science Standards and the National Science Education Standards. <https://schmidtocean.org/education/rv-falkor-inspired-lesson-plans>

LIVE ONLINE

Sign up for live ship-to-shore connections with your classroom during expeditions at <https://schmidtocean.org/education>. Watch archived remotely operated vehicle dives at www.youtube.com/user/SchmidtOceanVideos.

ARTISTS AT SEA

The SOI Artist-at-Sea program brings artists of broad disciplines onto expeditions to work together with scientists and crew to take inspiration from the research occurring aboard R/V *Falkor*. An open call occurs every December at <https://schmidtocean.org/apply/artist-residency-program>.

The work is showcased through traveling exhibits and can be viewed at <https://schmidtocean.org/collection/artist-at-sea>.

EXPLORE MORE

<https://schmidtocean.org/cruises>
www.youtube.com/user/SchmidtOceanVideos/videos

