Testimony of
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Hearing on: OCEAN EXPLORATION: DIVING TO NEW DEPTHS AND
DISCOVERIES

United States House of Representatives Committee on Science, Space, and
Technology
Subcommittee on Environment

Thank you, Chair Lizzie Fletcher, Ranking Member Roger Marshall and the other distinguished members of the committee, for holding this valuable hearing today and for giving me the esteemed privilege of providing testimony. It is an honor to be here to speak about the wondrous and breathtaking deep-sea environment that is not often at the forefront of everyday citizens' thoughts about the ocean. Such vital systems like deep-seamounts, coral reefs, hydrate seeps, and hydrothermal vents merit scientific understanding, sharing, and consideration. While the focus here today is the deep-sea, we must acknowledge that our ocean is an inextricable component of the system that allows all life to thrive here on Earth. I thank this committee for its efforts to shed light and facilitate discussion on a national level to address the significance of ocean exploration and the continued need for collaborative, technology-based research.

It is my great pleasure to appear before you today in my current capacity directing communications and outreach for [Schmidt Ocean Institute](#), a 501(c)(3) operating foundation established by Eric and Wendy Schmidt in 2009. Schmidt Ocean Institute aims to foster a deeper understanding of our environment by combining advanced science with state-of-the-art technology to achieve lasting results in ocean research, to catalyze sharing of the information, and to communicate this knowledge to audiences around the world. In my role, I share the exciting discoveries and important research that take place on the Institute's operating platform, research vessel *Falkor*.

As the only philanthropically-funded, international seagoing facility dedicated to year-round open ocean research, Schmidt Ocean Institute has positioned itself as a leader and collaborator with both international and U.S. academic institutions, government agencies, and non-governmental organizations. Working with Schmidt Ocean Institute for over five years has allowed me to experience firsthand the important role that science and exploration fulfills in the deep-sea. On every expedition we embark on, something novel is discovered. Whether a new species, seamount, biological or geological interaction, or development in technology; everyday that a research vessel spends at sea, expands our knowledge of the marine environment.

A statistic we often hear is that more is known about the far side of the moon than about the ocean, but I personally think the more important question to highlight is *why* do we know more about the moon than we do about the deep-sea? How do we create the excitement and passion for the systems that we cannot view from the beach, environments not observed by a telescope? How do we engage with citizens outside of the traditional marine and coastal communities to bring understanding of ocean health to America's heartland? Many observe the vastness of the ocean, but few comprehend the scale of the deep-sea.

The ocean is enormously deep, reaching 36,000 feet in its deepest trench. At nearly 7 miles below the surface this dark, cold environment, with crushing pressure appears like it would be inhospitable to life. However, this is not the case. Seemingly otherworldly habitats and uniquely adapted species are found in these secret habitats far away from the shorelines of our coasts. More than 90 percent of ocean habitat exists in the deep-sea, but less than 10 percent has been explored by humans. These difficult environments make deep ocean exploration technically challenging and, until recently, largely beyond human reach. But today, technology has allowed us to not only access these environments for study and research, but to share this exploration through live streaming video around the world to classrooms, aquariums, museums, and even smartphones and mobile devices.

Research vessel *Falkor* sailing into San Francisco, CA. Credit: Josh Edelson.

There are only three U.S.-based entities operating non-commercial deep-sea oceanographic research vessels, outfitted with embedded science work class remotely operated vehicle systems that are dedicated to yearly support of ocean exploration, research, and live at-sea outreach. Schmidt Ocean Institute is one of those organizations with its research vessel *Falkor*. While each vessel and entity has a unique focus, all three have sharpened national efforts to better understand the deep-sea.

As a philanthropic platform, Schmidt Ocean Institute has been able to emphasize high-risk, high-reward innovation in ocean science, robotic systems, and emerging technologies and software. Technology that advances the state of ocean science is an area where more national focus needs to be allocated, allowing for broader and faster data collection, management, analysis, and open sharing. As our global ocean changes, we need to be able to capture baseline data for hard-to-reach places and better understand how they will be affected or adapt to warmer ocean temperatures.

Additionally, we need to advance our understanding of how these deep systems interact and influence shallow environments.

The remaining part of my testimony will be divided into three sections that highlight essential components of ocean exploration. I will first discuss the need to define and measure fundamental ecosystem science in the deep ocean using seafloor maps, sensors, and digital imagery. I will then move to the technology - both existing and needed- that is necessary to accomplish national science obligations, highlighting how the use of such capabilities can be optimized and/or expanded. Last, I will emphasize the importance of sharing these exploration programs with the public and nurturing human connection to the deep-sea.

1.   OCEAN EXPLORATION AND DEEP-SEA ECOSYSTEM SCIENCE

Ocean exploration is not a new activity; however, past efforts have been limited by capacity, funding, and the availability of technology. Only in recent years have we had the technology to truly invest in detailed assessments, seafloor mapping and characterization of deep-sea environments. Philanthropic endeavors such as Schmidt Ocean Institute have helped to scale capacity and broaden the reach of ocean exploration (see Appendix A). For example, research vessel *Falkor* has contributed more than 1,385 self-funded science days at sea since 2013 and made all of the resulting collected data publicly available. While this effort contributes to our understanding, we are still lacking the data and capacity needed to fully characterize the ocean. Did you know that only about 15 percent of the ocean floor has ever been mapped? Think about that for a second. A simple topographic map is one of the most basic forms of environmental investigation, yet 85% of our ocean remains in obscurity. There are global efforts now underway, such as the United Nations Decade of Ocean Sciences and Seabed 2030 Project, an initiative jointly organized by the Nippon Foundation and the General Bathymetric Chart of the Oceans to encourage more mapping of the seafloor (their goal is a full mapped seabed by 2030). This is one example of the work needed to truly bring our understanding up to date and demonstrates why ocean exploration remains critical for ocean sciences and our nation.

Ocean Exploration and Ecosystem-Based Management

One of the best ways to close this data gap and lack of understanding is through multidisciplinary international collaborations that merge ocean mapping, morphology, geology, microbiology, chemistry, and even education. Schmidt Ocean Institute has endeavored to achieve this, bringing together 165 institutions from 30 different countries over the past six years to explore, collect data, and serve as a catalyst to accelerate the pace of ocean science and technology to innovate, discover, and share. These unique collaborations have led to new discoveries and knowledge that have both scientific and conservation implications.

For example, *Falkor* operated off the coast of Costa Rica earlier this year with collaborators from Temple University, Scripps Institution of Oceanography, and the University of Rhode Island, with

the goal of bridging conservation and scientific research. The [work expanded] knowledge of deep-sea ecosystems in the region and provided justification for possible expansion of Cocos Islands National Park to deep-seamount communities.

Chimaeras found in Costa Rican waters during the January 2019 expedition. Chimaeras are cartilaginous fish, largely confined to deep water.
Credit: Schmidt Ocean Institute.

This was the first survey of seven seamounts in the region, which act as an important migration corridor for the animals. One of the most important contributions science can make right now is to help managers understand how these communities work, to better prepare and assess future changes. The research will support efforts to provide a baseline of the incredible species and found in the deeper ecosystems that do not always attract the attention that they deserve.

During the expedition, four new species of deep-sea corals and six organisms were discovered. Uncovering new species increases our total knowledge about the ocean and how different organisms and systems interact. These discoveries provide an opportunity to unlock information on how our world works and demonstrates that there is still a lot more we can learn about our planet.

In 2014, *Falkor's* high-resolution maps of the Papahanaumokuakea Marine National Monument, northwest of the Hawaiian Islands, helped to illuminate the precious seamounts outside of the existing protected boundaries that led to the discovery of several new species. These efforts contributed to the justification for a significant U.S. government expansion of the protected area. This data collection was a result of Schmidt Ocean Institute making their unique seagoing asset available to U.S. scientists. Using these data, University of Hawaii researchers were able to see, measure, sample, and understand much more than before about the extensive biodiversity of the entire area, not just a small piece of this special area.

Even with the additional mapping of the region, there is still a significant portion that goes uncharacterized, and even more questions about the biology and its genetic connections to the rest of the Pacific. Research vessel *Falkor* will return to the Papahanaumokuakea Marine National Monument this summer to gain insight into the seamount lifeforms and their distribution across the region. This imperative work will provide ocean managers baseline knowledge of the fauna found on the seamounts and how they are connected to the broader central and western Pacific region. The protected waters could be a genetic source for other cobalt-rich regions. The research will also help to better understand the impact of ocean acidification on the formation of deep corals.

This foundational science is the type of work that is needed across the entire Pacific region. Mapping and surveying deep-ocean systems will present a better picture about why ocean species exist in certain places and help scientists and managers to better understand the sensitivity of these ecosystems and migration patterns to changes in ocean climate.

Digitizing Marine Life and Seafloor Habitats

A plethora of submarine activity can be found on the seafloor where heat, water, and gases interact, creating otherworldly ecosystems that host unique organisms and structures. Unfortunately, available observations of these marine habitats are patchy, discontinuous, and scarce; it is not known how these deep-sea ecosystems connect to the broader ocean food chain that supports our commercial fisheries. More quality data is essential to inform effective management. Schmidt Ocean Institute, in collaboration with scientists who sail aboard *Falkor*, is helping to expand the data available through digital characterization of marine habitats and processes for subsequent research, analysis, and open sharing.

Schmidt Ocean Institute's 4500 meter capable remotely operated vehicle (ROV) SuBastian. Credit: Schmidt Ocean Institute.

Currently, the best way to collect this data is through the use of a remotely operated vehicle (ROV). Schmidt Ocean Institute's ROV SuBastian uses 4K cameras to visually collect and share these remote coral and hydrothermal systems. Using the highest quality resolution of approximately 4,000 pixels allows for crisp lifelike imagery that illuminates ocean habitat as if you were there. Exploratory dives with SuBastian have revealed extraordinary microbial communities, vent systems, and new species. For example, rare animals like the seven-legged octopus were viewed for the fourth time ever this past year, as well as several species not previously known to scientists.

Hydrothermal vents are an expression of submarine volcanism located near areas of tectonic plate movement known as ocean ridges. The vents are part of a globally important process known as sea-floor spreading, which plays a vital part in shaping the surface of our planet. These sites serve as a natural laboratory to document the life cycles of incredible, alien-like organisms and better understand how they survive in extremely challenging environments. The vents are systems of geologic activity where submarine volcanism results in high-temperature venting with unusual chemistry and geology. Ocean exploration should not stop with the species or the vent systems; the interactions between deep and shallow environments is critically important to better appreciate their influence on each other.

Since October of 2018, Schmidt Ocean Institute has participated in three expeditions in the Southern Pescadero Basin, an area off the Gulf of California. Using submarine robotics systems managed from research vessel *Falkor,* the science teams successfully mapped the ocean floor in high resolution leading to the discovery of new hydrothermal vent fields, never seen before species, and unique underwater worlds.

Superheated hydrothermal fluid flows upwards from an underwater volcano 2000 meters below the Gulf of California. Credit: Schmidt Ocean Institute.

At 2,000 meters depth, towering mineral structures (up to 23 meters in height) serve as biological hotspots for life. These newly discovered geological formations feature upside down 'mirror-like' lakes that pool hot fluids (up to 366ºC) and create the illusion of looking at a mirror when observing the superheated hydrothermal fluids beneath them. A seemingly inhospitable habitat, with metal-laden minerals and highly sulfidic fluids, yet these sites were teeming with biodiversity. This may be a clue to how life exists in less habitable environments on other planets.

Voyages to the Pescadero Basin are a good reminder of the locations around the world that remain unexplored, yet prove to be important locations for understanding how vent fauna colonize similar sites around the globe. The detailed work at this site will further allow investigation of the geological and geochemical controls on habitat suitability for different animal and microbial communities.

Broader Ocean Impacts

The deep ocean not only supports vent systems and animals, but provides habitat for a wide array of species and works to remove carbon dioxide from the atmosphere. However, a 2017 paper by Sweetman et al. forecast that up to 55 percent of the deep ocean seafloor could be significantly impacted by 2100, starving the animals and microbes that exist. Ecosystem shifts as a result of changing temperature, pH and oxygen levels are predicted to impact these sensitive ecosystems. The situation could be exacerbated by drilling for oil and gas, dumping of pollutants, over-fishing, and deep-sea mining. Little is known about how a changing climate will impact the deep-sea, and more is needed to truly understand these impacts. Ocean exploration is one mechanism for not only characterizing what exists but also for discovering the complex pathways and interactions between biological and physical components of the Earth system. Understanding these pathways and interactions are essential for making projections of the future environment.

What is known is that there is methane stored in ocean sediments, and gas released from the seafloor goes into the ocean. Where this methane goes and how it is transformed in the water ultimately dictates the magnitude of its role. The large flux of methane into the ocean means it may indirectly play a part in the carbon cycle, which is closely linked to Earth's climate. In October of last year, a science team from Harvard University and NASA worked in the Southern California Borderland and showed that methane venting is much more episodic than previously known, changing our assumptions about methane escape from the seafloor.

Several other expeditions have focused on deep-sea methane as well, examining bubbles coming from the sea floor to better understand the gases being emitted and how they travel through the ocean to the atmosphere. Last year, scientists from Woods Hole Oceanographic Institution, while sailing aboard research vessel *Falkor*, examined gas samples with a new bubble capture system that was installed on ROV SuBastian to take chemical measurements of bubble composition. The research illustrated changes in methane from venting locations across a spatial scale and over time. By studying methane bubble concentrations scientists will be able to advance understanding of the biological storage for methane and develop new ways to understand ocean cycles.

Mylar Frozen balloon found in the Pescadero Basin more than two miles below the ocean surface. Credit: Schmidt Ocean Institute.

Aside from changing climates, humans are also impacting these exceptional ecosystems. Unfortunately, even in these remote and beautiful environments we have seen an accumulation of trash. During a recent ROV SuBastian dive in the Pescadero Basin at 3,600 meters depth (more than 2 miles), an accumulation of garbage was discovered including fishing nets, deflated Mylar balloons, and even a discarded fully-decorated Christmas tree! Bearing witness to garbage covering our seafloor is becoming more frequent on our ROV SuBastian dives and is a stark juxtaposition to the spectacular mineral structures and biodiversity we find at deep depths.

2. OCEAN EXPLORATION AND TECHNOLOGY

The ocean is far too large to observe with current conventional means. In order to make meaningful advances in ocean exploration research there must be a comprehensive network of agile, resilient, and robust platforms. Ocean managers urgently need swift monitoring and improved tools to track and counter declining ecosystem conditions. Better data and monitoring capacity will play a central role in improving exploration outcomes. This means not only implementing robust technologies

in our own waters of North America, but expanding them globally to include remote and developing countries. Robotic systems coupled with artificial intelligence can complement existing vessels and platforms. When deployed in groups, autonomous vehicles will improve coverage and cost-efficiency for making select ocean observations, reducing risk and facilitating high resolution spatially distributed surveys of dynamic marine processes. The following projects provide examples of work to prototype the platforms on which the future of ocean observing can be built.

Scalable Ocean Research with Autonomous Robots and Artificial Intelligence
The ocean is Earth's life support system. To properly conserve this fundamental resource, the ocean's dynamic processes must be observed with higher resolution and coverage in time and space than what is currently possible with dedicated research ships alone. A multi-platform approach with low-cost autonomous vehicles deployed from research vessels in different mediums including underwater, sea surface, and air, can allow for a more comprehensive and complete picture of our oceanic systems. The cost-efficient robotic technologies available now and under development can allow us to achieve the levels of persistence and resolution of observations required for scalable ocean studies in a changing climate.

Multiple autonomous vehicles - aerial and underwater - utilized by scientists and engineers during a 2018 expedition aboard research vessel *Falkor*. Credit: Schmidt Ocean Institute.

Schmidt Ocean Institute has focused on scalable ocean research supporting the use of coordinated robotics from its ship, offering time at sea for both the collection of science and the development and testing of robots and smart software for autonomous marine surveys. Schmidt Ocean Institute is one of the first philanthropically funded exploration vessels to be used as a command center and test platform for the operation of multiple independently-unique vehicles simultaneously, allowing engineers and scientists to refine their techniques. The success of this model should be broadly adopted to accelerate the pace and ability of research for ocean exploration. In 2018, Schmidt Ocean Institute completed several expeditions devoted to developing and testing software that maximized informational contributions of multiple autonomous vehicles to the description of target habitats. The results of this work led to greater mapping, data and characterization efforts.

A specific example of this approach took place when a team of international collaborators allowed for coordinated robotic systems to collect over half a million georeferenced images covering 77,453 m^2 of seafloor in U.S. waters. This expedition aboard *Falkor* was an opportunity to test techniques that automate ocean observing. Another Schmidt Ocean Institute expedition used unsupervised learning techniques with 3D reconstruction to analyze 1.3 million seafloor images

collected between autonomous unmanned vehicle deployments. As a result, the largest known continuous photogrammetric reconstruction of seafloor mapped at sub-centimeter resolution was created from data collected off the coast of Oregon.

These projects demonstrate how throughput data processing and machine learning can multiply the productivity of ocean exploration. They allowed scientists to make quick and well-informed decisions on how to directly sample and conduct fine scale surveys to study rapidly changing marine habitats that would otherwise be virtually impossible to observe in detail. The resulting work is invaluable in planning operations, including the recovery of seafloor instruments, re-visiting active bubble plumes, and making operation more efficient.

More ocean observations like these are critical to creating actionable science building our nation's ability to understand and manage our ocean resources. The volume of ocean observations is growing at an accelerating pace, but the infrastructure to transmit, store, process, and analyze these data remains in infancy. Thus, even with greater observational capabilities, a substantial amount of development will be required to build systems that facilitate transformation of the data into fact- and science-based ocean management. Many conventional workflows for marine data processing are not automated, inhibiting the productivity of scientists and managers. Strategic focus on projects automating marine data analysis workflows is needed to accelerate the understanding of our rapidly changing marine habitats and multiply the conservation benefits.

Ocean Worlds

While we still have much to discover here on Earth, scientists are also looking to other oceans in our solar system. On Europa, one of Jupiter's moons, geyser-like features shoot more than a hundred miles into the air. If and when humanity takes the plunge into the ocean of another world, we will have to create innovative ways to operate and communicate. In preparation for such endeavors, deep ocean systems are the closest analog on Earth to these other ocean worlds and can serve as a laboratory to develop and test new communication tools and technology for use in extraterrestrial exploration.

The ABISS lander in action. Credit: Schmidt Ocean Institute.

By working in the deep ocean, we can push the limits of our understanding of existing hardware designs and engineering choices for missions in outer space. Last year Schmidt Ocean Institute hosted four expeditions where software and robotics targeted for space exploration were engineered and tested. One took place off the coast of California deploying NASA's Planetary Science Technology Analogue

Research (PSTAR) funded Autonomous Biogeochemical in situ Sensing System (ABISS) lander. The team from Harvard University and NASA worked together to refine the lander and produce a comprehensive map of the contiguous seeps in the Southern Borderland, reshaping our understanding of connectivity among these habitats.

3. **OCEAN EXPLORATION AND REACHING THE PUBLIC**

Unique journeys of discovery and exploration in the deep ocean are not fully actualized unless the wonder and scientific value of the work reaches the communities, schools, workplaces, and living rooms that are affected—whether they know it or not—by events in the vast expanse of the deep sea. Being able to share the joy and excitement of discovery and achievement is as critical as the work itself.

Every day we should aim to inspire a passion for the ocean by sharing enthralling footage and bringing the latest in ocean research to people all over the globe. Communicating this work through dedicated outreach programs that target wide audiences is essential to making connections between the public and deep-sea. This especially rings true for communities who have these environments in their backyards, yet have no knowledge or access to them, and to other groups in landlocked regions with no day-to-day tangible connections to the ocean.

Making ocean exploration and marine science accessible to the public, anyone can learn about the research taking place and its effect on their lives. It is important to not just make data and imagery available, but to synthesize them into programs and materials that are useable for engaging a wide spectrum of audiences. Schmidt Ocean Institute makes all of its live dives available in perpetuity on our [YouTube channel](), and the [4K highlights]() and [weekly expedition videos]() that have been viewed by more than half a million people. This demonstrates that there is a desire among Americans and the global community to learn more about the ocean—especially the strange and mysterious reaches of the deep ocean. Organizations focused on ocean observation can capitalize on this interest and build momentum for expanding observational efforts. Translating materials into languages other than English can further increase the impact of the resources devoted to exploring the deep sea.

Ocean exploration was once conducted in remote regions where public engagement was next to impossible. This has changed, however, with a growing number of scientists and institutions looking to expand their reach and demonstrate the value of their work. Scientists now connect with local communities, artists, students and scientists using data visualization, technology, and the arts. These mechanisms enable broader understanding of the ocean and offer learners new opportunities to engage and train in ocean sciences. The goal of these efforts is to encourage the public to rethink the way marine science is shared and break down the complexities of ocean research. Ocean exploration lends itself to interactive storytelling and engagement, via a plethora of innovative outreach programs. Such programs should not only continue to be supported on a national level,

but successful programs must be identified, expanded, and replicated across different disciplines and locations.

One example of a particularly successful method for engaging the public with ocean science is Schmidt Ocean Institute's [Artists-at-Sea program](#) that invites artists to participate in ocean exploration expeditions. The artists interpret and visualize the science conducted through various art forms, which can speak to new audiences making the subject matter approachable and understandable. [Projects have ranged](#) from light painting performances, oceanscape resin art, woodworking sculpture, portrait painting, cyanotype prints, and a life-size mural of the *Pseudoliparis swirei* ghost fish. The success of this program has resulted in more than 25 artists sailing, whose 118 pieces of work have been put together in a traveling exhibit that has reached 15 different US venues in 11 different cities including the Aquarium of the Pacific, the International Ocean Film Festival, the America's Cup race, and will open this week at the Michigan Science Center.

Education should be a top priority for ocean exploration programs to encourage student learning with hands-on opportunities and provide experience and career guidance via live engagement. Student participation programs for entry at different age groups is important to developing lifelong connections to the sea. Remote participation with [ship-to-shore connections](#) for middle school groups, internships for college students, and direct training and mentoring for graduate and early career scientists are additional ways to engage interested populations.

CONCLUSIONS
The public faces daily messages of negativity surrounding our environment and ocean. During this time of environmental decline, ocean exploration can provide a new narrative, bringing a message of hope. Exploration provides the opportunity to showcase beautiful and mysterious parts of the ocean that are rarely observed to millions of people. The ocean is changing, but new data, science, and dedicated people can bring a fresh understanding and engagement with the deep-sea. Ocean exploration has an opportunity to accelerate this understanding and demonstrate our responsibility to care for the ocean, which remains a critical need for the ocean sciences, as well as our nation.

The House Committee on Science, Space, and Technology can help advance the conversation about how we as a nation can stimulate ocean exploration to advance science, technology, and education. Ocean exploration is critical to better understand the Earth's complex systems, better protect them, and work towards a long-lasting positive connection between humans and the ocean that supports us all, no matter where we live.

We need to leverage economies of scale to decrease the cost of sensors and systems to make them available to more people, to cover more ocean, to build capacity in technology-poor regions, and to protect deep-sea resources where they are vulnerable. Access to emerging technologies is

critical in capacity building, but it cannot be just about the technologies. International collaboration and support is needed to address management and protection of global resources. More investment is needed in data standards, archiving, accessibility & analysis, with consideration for data rights. We should look for advances in other industries that can be applied to the greatest challenges in ocean observations; many exciting innovations are happening across technology sectors, such as medical, oil and gas, defense, etc. that could be applied to general ocean exploration and research. Finally, education must remain a top priority for ocean exploration programs, providing programmatic and financial support for student learning and public engagement.

Globally, we can position ocean exploration for high-risk, high-reward, conservation-minded ocean science as evidenced by some of the examples I have shared today. Achievement of these goals can be accelerated by continuing and increasing emphasis on technology development, leveraging innovative platforms for far-reaching communication, and facilitating international collaboration between the best oceanographic scientific minds. I will leave you with a question: What is the greatest difference between Earth—our home—and other planets in our solar system? What do astronomers look for when they search for other planets that might harbor life? The answer is oceans! Our ocean is vitally important to our existence, and life on this planet—not just life in the ocean—is deeply dependent on the state and health of our ocean waters. The more we know about the unexplored depths of the deep sea, and the more we know about how the deep sea interacts with ecological and human systems, the more we will understand how the ocean affects us on the continuum of human experience: from the fish on our dinner plates to the long-term future of our species. The research and development discussed here today is critical for optimal decision making and stewardship of our oceans and to the health, economy, and security of our nation. Chair Fletcher, Ranking Member Marshall, and members and staff of the committee, thank you once again for your invitation to testify here today, and I look forward to answering any questions you may have.

Appendix A: Deep Sea Ocean Exploration Research Expeditions on Research Vessel Falkor

Expedition Title	Year	Lead Principal Investigator	Region/Area	Country of Work	Collaborators	Vehicles
Microbial Mysteries: Linking Microbial Communities and Environmental Drivers	2019	Mandy Joye	Baja Peninsula	Mexico	University of Georgia, Max Planck institute for Marine Microbiology, Harvard University, Coastal Carolina University, Universidad Nacional Autónoma de México,	Remotely Operated Vehicle (ROV) SuBastian, Lander
Costa Rican Deep Sea Connections	2019	Erik Cordes	Costa Rican Shelf	Costa Rica	Temple University, University of Costa Rica (Centro de Investigación en Ciencias del Mar y Limnología), Scripps Institution of Oceanography, University of Rhode Island, California Institute of Technology	ROV SuBastian, ship-towed autonomous vehicle Wire Flyer
New Approaches To Autonomous Exploration At The Costa Rican Shelf Break	2018	Richard Camilli	Costa Rican Shelf	Costa Rica	Woods Hole Oceanographic Institute,Australian Centre for Field Robotics (University of Sydney), National Aeronautics and Space Administration, Massachusetts Institute of Technology, Univeristy of Michigan, University of Athens	ROV SuBastian, Slocum Gliders,
Interdisciplinary Investigation of a New Hydrothermal Vent Field	2018	Robert Zierenberg	Baja Peninsula	Mexico	Monterey Bay Aquarium Research Institute, University of California - Davis, California Institute of Technology, Occidental College, Scripps Institution of Oceanography, Oregon State University, University of Rhode	ROV SuBastian, Autonomous Underwater Vehicle (AUV) D. Allan B (MBARI Mapping AUV)

				Island, Pontifica Universidad Catolica de Chile	
Characterizing Venting and Seepage Along the California Coast	2018	Peter R. Girguis	Coast of Southern California	United States of America	Woods Hole Oceanographic Institute, Harvard University, Texas A&M University, National Science Foundation, National Aeronautics and Space Administration	ROV SuBastian, Autonomous Biogeochemical Instrument for In Situ Studies (ABISS) Lander
Hunting Bubbles: Understanding Plumes of Seafloor Methane	2018	Anna Michel and Scott Wankel	Oregon and Washington Coast	United States of America	Woods Hole Oceanographic Institute, Harvard University, Texas A&M, National Science Foundation, National Aeronautics and Space Administration	ROV SuBastian, ChemYak (Autonomous Surface Vehicle)
Adaptive Robotics at Barkley Canyon and Hydrate Ridge	2018	Blair Thornton	Oregon and Washington Coast	United States of America	University of Southampton, University of Tokyo, Kyushu Institute of Technology, Universitat de les Illes Balears, Tokyo University of Marine Science and Technology, National Oceanography Centre, Australian Centre for Field Robotics, Grey Bits Engineering, Japan Agency for Marine Science and Technolgoy, University of Aberdeen	ROV SuBastian; University of Tokyo AUVs: AE2000f, TUNA-SAND, TUNA-SAND 2
The Seeping Cascadia Margin	2018	Susan Merle	Oregon and Washington Coast	United States of America	Pacific Marine Environmental Laboratory, Oregon State University, Schmidt Marine Technology Partners	None (Onboard multibeam sonar mapping)
Solving Microbial Mysteries with	2018	Andrew Babbin	Coast of Baja Peninsula	Mexico	Standford University, Massachusetts Institute	ROV SuBastain

Autonomous Technology				of Technology (Babbin Laboratory)	
Voyage to the White Shark Café	2018	Barbara Block	Pacific Ocean	United States of America	Standford University, Monterey Bay Aquarium Research Institute, Monterey Bay Aquarium, National Oceanic and Atmospheric Administration, University of Delaware, Saildrone, The Aspen High Seas Initiative (Aspen Institute), The Aquarium of the Pacific, Argos System	ROV SuBastian, Slocum Glider
Underwater Fire: Studying the Submarine Volcanoes of Tonga	2017	Ken Rubin	Tonga Arc Region	Kingdom of Tonga	School of Ocean and Earth Science and Technology (University of Hawaiʻi at Mānoa), Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, University of Washington, GNS Science, Oregon State University, Point Loma Nazarene University	ROV SuBastian, AUV Sentry
Discovering Deep Sea Corals of the Phoenix Islands	2017	Erik Cordes	Pheonix Islands	Republic of Kiribati	Temple University, Boston University, Woods Hole Oceanographic Institute, Baruch College, National Oceanic and Atmospheric Administration	ROV SuBastain
Searching for Life in the Mariana Back-Arc	2016	David A. Butterfield	Mariana Trench	Pacific Ocean	University of Washington, Oregon State University, National Oceanic and Atmospheric Administration, Pacific	ROV SuBastian

					Marine Environmental Laboratory, Marine Biological Laboratory	
Ecosystem Dynamics of Hydrothermal Vent Communities	2016	Chuck Fisher	Coast of Fiji	Fiji	Columbia University, Harvard University, Pennsylvania State University, Woods Hole Oceanographic Institute	ROV ROPOS
Virtual Vents: The Changing Face of Hydrothermalism Revealed	2016	Tom Kwasnitschka	Coast of Fiji	Fiji	Helmholtz Centre for Ocean Research Kiel (GEOMAR), Memorial University, University of Victoria, Deutsches Forschungszentrum für Künstliche Intelligenz (German Research Center for Artificial Intelligence), University of Ottowa, United States Geological Survey	ROV ROPOS
Hydrothermal Hunt at Mariana	2015	Tamara Baumberger	Mariana Trench	Pacific Ocean	University of Washington, Oregon State University, National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory	AUV Sentry
Magnetic Anomalies at the World's Largest Volcano	2015	William Sager	Coast of Japan	Japan	National Science Foundation, NGS, University of Houston, Texas State Aquarium, CHIBA University	None (Onboard multibeam sonar mapping and magnetometer reading)
Perth Canyon: First Deep Exploration	2015	Malcolm McCulloch	Perth Canyon	Australia	Australian Government, University of Western Australia, Western Australian Museum, Commonwealth Scientific and Industrial Research Organisation, Institute of Marine Science	ROV Comanche

Expanding Mariana Trench Perspectives	2014	Douglas Bartlett	Mariana Trench	United States of America - Guam	National Science Foundation, Scripps, Woods Hole Oceanographic Institute, Prince Albert II of Monaco Foundation, Office of Navel Research Science and Technology, National Aeronautics and Space Administration	Schmidt Ocean Institute Lander (Full Ocean Depth)
Exploring the Mariana Trench	2014	Jeffrey Drazen	Mariana Trench	United States of America - Guam	National Science Foundation, National Oceanic and Atmospheric Administration Fisheries, University of Hawaii, Whitman College, University of Aberdeen, National Institute of Water and Atmospheric Research, Natural Environment Research Council, National Oceanography Centre	Schmidt Ocean Institute Lander (Full Ocean Depth)
The mysteries of Ontong Java	2014	Michael Coffin	Ontong Java Plateau	Kingdom of Tonga	University of Tasmania Institute for Marine and Antarctic Studies, Australian Government, Natural Environment Research Council	n/a
The Iron Eaters of Loihi Seamount	2014	Brian Glazer	Loihi Seamount, Hawaii Island	United States of America	University of Hawaiiat Manoa, Woods Hole Oceanographic Institution, Institut Français de Recherche pour l'exploitation de la Mer (IFREMER), University of Minnesota	AUV Sentry
Papahanaumokuakea Monument	2014	Christopher Kelley	Northwestern Hawaiian Islands	United States of America	University of Hawaii, National Oceanic and Atmospheric Administration	N/A

					National Marine Sanctuaries, National Science Foundation, University of British Columbia, University of Sydney	
Axial Seamount	2013	Julie Huber	Axial Seamount, Vancouver Island	Canada	Marine Biological Laboratory, University of Massachusetts, National Science Foundation, Gordon and Betty Moore Foundation, University of Washington, J. Craig Venter Institute	ROV ROPOS
Open Ocean to Inner Sea	2013	Richard Dewey, Maia Hoeberechts	Juan de Fuca Strait and the Salish Sea, Vancouver Island	Canada	Ocean Networks Canada, University of Victoria, Natural Environment Research Council, Canada Foundation for Innovation	ROV ROPOS
Hydrothermal Exploration of the Mid-Cayman Rise	2013	Christopher German	Mid-Cayman Rise, Caribbean Sea	Cayman Islands	Woods Hole Oceanographic Institution	HROV Nereus