ANNUAL REPORT 2018

Woods Hole Oceanographic INSTITUTION

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This annual report is published by Woods Hole Oceanographic Institution. Although the greatest possible care has been taken in preparing this record, we recognize the possibility of omissions or inaccuracies. If any are noted, please accept our apologies and advise us of any corrections to be made.

About the Cover:
Orpheus, an autonomous underwater vehicle (AUV) developed in 2018 by WHOI, begins its descent into Veatch Canyon on the continental shelf off of the U.S. Northeast coastline during one of several dives from the R/V *Neil Armstrong* in September 2019.

Designed by WHOI lead engineer Casey Machado and WHOI deep-sea scientist Tim Shank in collaboration with NASA's Jet Propulsion Laboratory, the AUV is a critical component of WHOI's Deep Ocean Hadal Exploration Program. The small, lightweight vehicle is the first in a new class of AUVs designed to withstand the pressure of the ocean's greatest depths, while working independently or as a networked "fleet" to explore and conduct research in the deepest parts of our planet.

Front cover photo by Ken Kostel, WHOI | Back cover photo by Simon Thorrold, WHOI

A Message from the Chairman and the President

Every year the scientists, engineers, and technicians at Woods Hole Oceanographic do more, take on greater challenges, and push ocean science to new heights. As you will read in the stories and highlights contained in this annual report, 2018 was no exception.

Over the course of the year, WHOI attracted international attention and unprecedented funding for our new Ocean Twilight Zone Project, which kicked off with a $35 million commitment from the Audacious Project at TED and a prominent place on the main TED stage in Vancouver. In less than one year, the project has shown the promise we laid down for it from the beginning: to chart a disruptive course for ocean science and to pursue answers to urgent questions for a critically important yet little-known part of the global ocean.

The year also marked 50 years of academic excellence for the world-renowned MIT-WHOI Joint Program in Ocean Science and Engineering. The program has produced more than 1,000 graduates, many of whom are now leaders in ocean science and engineering, as well as policy, industry, and national defense.

We also took a major step in raising WHOI's visibility and attracting new audiences and greater support than ever before. Thanks to a core group of trustees who pledged $5 million to the effort, we launched the WHOI Advancement Initiative, bringing in new Vice President for Advancement and Chief Marketing Officer, Samuel Harp, in late 2018. Sam has plotted an ambitious, results-oriented strategy aimed at accelerating our fundraising, engagement, and communications activities. We are already beginning to see results as fundraising picks up speed and WHOI actively promotes its leadership role in areas such as Ocean and Climate, Human Impacts, Ocean Stewardship and Sustainability, the Ocean Twilight Zone, and the Future of Oceanography.

On the governance front, the Board took the lead in managing WHOI's finances in a changing funding climate and helped steer plans for infrastructure projects needed to keep WHOI at the forefront of ocean science. Chief among these is the renovation of our waterfront facilities, the heart and soul of marine operations at WHOI and throughout the ocean science community. In addition,

we set out to reinvigorate WHOI's Corporation engagement by adding several new faces and have seen positive results so far, particularly in the energy and ideas they bring. Finally, WHOI's New York, New England, and Dallas Chapters are gaining ground in meeting their goals of creating excitement and building support for WHOI with events that have engaged new prospects around the country.

Many of the most pressing issues facing society today—climate change, hunger, national security, and pollution among them—touch on humanity's relationship with the ocean. WHOI's role as a leader in understanding the ocean at a fundamental level and in untangling the complexity behind these issues means that we stand at the forefront of the greatest challenge of all: helping humanity chart a path towards a sustainable future on the only planet we have to call home.

We are most grateful to our supporters for recognizing the importance of our work and for joining us in this mission. Your commitment to ocean science, exploration, and education at WHOI provides the momentum that keeps us moving forward.

We hope the contents of this report demonstrate for you the impact we are making together as we strive to understand our ocean and the challenges it faces for the benefit of all who share our planet.

Photo by Danielle Fino, WHOI

David Scully
Chairman of the Board

Mark Abbott
President and Director

A Paradigm Shift for Ocean Technology

Innovators Award 2018

Dana Yoerger is the second recipient of the Center for Marine Robotics Innovators Award.

Photo by Jayne Doucette, WHOI

A tech revolution is underway in ocean research that is vastly expanding the potential for ocean exploration and discovery. Scientists and engineers at Woods Hole Oceanographic Institution are at the forefront of this transformation, developing game-changing technologies and methods that improve the way ocean environments are studied.

With a focus on creating new tools that are better, cheaper, faster—and more autonomous—we're breaking down the constraints of time and space that have traditionally held oceanographers back. We're illuminating life in the largely unexplored ocean twilight zone using acoustics and intelligent robots that can mimic the behavior of the animals they track. Small, cost-effective ocean sensors are being developed that can monitor previously inaccessible parts of the ocean and transmit measurement data anywhere, anytime. And next-generation deep-sea robots are being developed to explore the limits of life in the deepest ocean trenches.

2018 was a significant year for WHOI in pushing this technology paradigm shift forward:

- *Orpheus,* a compact and lightweight deep-sea robot, was developed to explore life in the Earth's hadal region, which extends from 6,000 to 11,000 meters (20,000 to 36,000 feet).

- New under-ice glider technology was developed to survey ice thickness across the Arctic ocean for weeks at a time, using the power draw of a cell phone battery.

- Aerial drones were used to non-invasively collect whale blow samples and give critically endangered right whales a high-tech checkup.

- WHOI engineers and scientists designed a small autonomous submersible—*Mesobot*—that will unobtrusively follow individual animals through the dimly lit waters of the ocean twilight zone and gather high-resolution images of its targets.

- Autonomous ocean gliders tracked changes in the Gulf Stream during Hurricane Florence and relayed data in near-real time to hurricane forecasters in an effort to help improve predictions of the storm's path and intensity.

- Arrays of Ocean Observatories Initiative (OOI) moorings, robotic vehicles, and ocean gliders provided researchers with "always on," access to biological, chemical, and physical data from remote, dangerous, and previously inaccessible parts of the ocean.

2018 was also an important year for two of WHOI's flagship underwater vehicles, *Alvin* and *Sentry*. These workhorses of oceanography reached significant milestones thanks to a series of periodic vehicle upgrades including new sensors and lighting systems, high-definition imaging, and control systems:

- The human occupied vehicle (HOV) *Alvin* made its 5,000th dive in the fall of 2018. During its 55-year career, thousands of scientists have leveraged *Alvin* to uncover vital secrets of the deep, and it has remained at the forefront of ocean science and exploration.

- *Sentry*, a free-swimming autonomous underwater vehicle (AUV) that has been used in range of mission-critical applications, made its 500th dive in 2018.

As the ocean environment continues to evolve and present new research challenges, WHOI will continue to pave the way forward by leveraging new and enabling technologies and expanding our engineering talent and expertise. We will also continue to foster a relentless culture of innovation—a true innovation engine—that brings to bear ideas that were once impossible to imagine The robots we're building for ocean research on Earth, for example, are inspiring a new class of vehicles for exploring oceans on the moons of other worlds like Jupiter and Saturn. And new sensor technologies we're bringing below the surface today are moving us one step closer to a future ocean that is continuously-monitored and always connected.

Education Experience

MIT-WHOI Joint Program students sampling Great Salt Marsh, Barnstable, Massachusetts.

50 Years of Education Excellence

In 1968, two esteemed scientific institutions launched an unorthodox academic experiment: Each would remain fiercely independent, but they would jointly coordinate a graduate program to educate and train ocean scientists and engineers.

Today, the MIT-WHOI Joint Program in Oceanography and Applied Ocean Science and Engineering is world-renowned, with nearly 1,000 graduates, many of whom have gone on to become leaders in the field and made valuable contributions in research, teaching, government, industry, and the Navy.

"Woods Hole had a vast laboratory, which was the ocean," said Howard W. Johnson, president of MIT the year the program was created. "We had the classrooms and the students who were interested in that laboratory. So the connection was natural."

To toast the golden anniversary, both institutions celebrated with two days of festivities on their respective campuses in Cambridge and Woods Hole in September 2018. Events included a symposium in MIT's Wong Auditorium with faculty, guests, and alumnae/i representing a diverse range of careers and a reception at WHOI with reflections from Joint Program leadership on the program then and now.

As of September 2018, the program had awarded 1,053 degrees (764 doctoral, 58 engineer's, and 231 master's degrees). Of the roughly 700 scientific papers published per year by WHOI scientists, more than 100 are co-authored by Joint Program (JP) students. On about 60 papers per year, JP students are first authors.

"Anyone who has worked with JP students or seen them in action knows how they contribute to the WHOI culture and research," said James Yoder, WHOI Dean of Academic Programs from 2005 to 2016. "In fact, it's hard to distinguish between JP education and research."

Audiences at the MIT and WHOI receptions also applauded the announcement that Delle Maxwell and Pat Hanrahan made combined $2.5 million gifts in honor of Delle's father, Arthur E. Maxwell. In 1965, Maxwell joined WHOI to serve as WHOI's Director of Research and Provost and played an instrumental role in the development of the Joint Program.

Of the total gift, $1 million goes to the Arthur E. Maxwell Graduate Student Fund at WHOI, established in 2003 by Jamie Austin (Ph.D. '79) to honor his mentor by providing annual support for first-year graduate students. The remaining $1.5 million goes to the MIT Department of Earth, Atmospheric, and Planetary Sciences to endow the Maxwell-Hanrahan Fund for Education and Research, which will fund opportunities for students to carry out oceanographic research at sea and set them on a course to take on some of the most pressing challenges of their generation.

"Never before has an oceanographic education been so important," said Matt Jackson (Ph.D. '08) the final speaker at the symposium in Cambridge. "Basic research is desperately needed on Earth's remaining frontier. Oceans are ground zero for climate changes, rising sea levels, ocean acidification, new species, coral reef damage, deep-sea mining, and impacts on marine ecology. These are huge issues, some of the most pressing issues we face, and the MIT-WHOI Joint Program is perfectly positioned to train scientists to address these issues."

Photo by Laura Castaon, WHOI

Photo by Lauren Heinen, WHOI

Back on Land
MIT-WHOI Joint Program students pose aboard the *Corwith Cramer*, SSV after returning from the 2018 Jake Peirson Annual Summer Cruise.

Policy Impact: Ocean Twilight Zone

The ocean is central to life on Earth, but it can be hostile to humans. For air-breathing land animals like us, the vast majority of our planet, including a critically important part of the ocean known as the twilight zone, is largely off-limits. Yet remote and difficult to access parts of the world, such as the twilight zone, provide significant benefits to humans around the world.

Porter Hoagland and Di Jin at WHOI's Marine Policy Center have been working to understand the goods and services the ocean provides humans every day. By doing so, they hope to strengthen decision frameworks for international policymakers who are deciding how to conserve the resources of the twilight zone before commercial fishing begins in earnest.

In September 2018, the United Nations began a series of international conferences aimed at creating a new, legally binding, international agreement focusing on the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction, also known as the "high seas." Despite the growing awareness by marine scientists of the importance of the twilight zone to the rest of the ocean, the ecosystem services it provides have been largely ignored during early phases of negotiation, something that Hoagland, Jin, and others have set out to change.

Through a partnership with the Deep Ocean Stewardship Initiative (DOSI), Hoagland obtained access to the first two Intergovernmental Conferences (IGCs) at UN Headquarters in New York to introduce delegates to the fundamental role that the twilight zone plays in supporting human welfare and making the planet livable.

The most significant ecosystem services supplied by the twilight zone are the so-called provisioning and regulating services. Provisioning services include flows of food, genetic resources, or biological materials or pharmaceuticals to society. Small fish known to inhabit the twilight zone, including the bristlemouth, the most common vertebrate on Earth, not only help feed commercially important fish such as tuna and swordfish, but they may present an untapped source of protein for Earth's growing human population as well.

"Some countries have already said they want to start fishing the twilight zone intensively," said Hoagland. "We have to ask about the implications of this to the twilight zone fish stocks as well as to the supply of other ecosystem services."

One implication could be to disrupt a second type of service the twilight zone provides known as a regulating service. Concentrations of carbon dioxide in the atmosphere recently passed 400 parts per million (ppm), which is raising global temperatures and disrupting climate worldwide. Without fish in the twilight zone helping to move carbon from the surface to the deep ocean, where it can remain safely sequestered for thousands of years, that number could be as much as 200 ppm higher. But the actual amount is in question, and reducing the uncertainty surrounding the number is a focus of intensive scientific research at WHOI and elsewhere.

"With a more accurate estimate of ocean carbon sequestration, society could make better-informed decisions regarding the mitigation of CO_2 emissions," said Hoagland.

Porter Hoagland,
Senior Research Specialist

Illustration by Mark Holmes, WHOI | Photo montage by Paul Caiger, WHOI

Research and Education Highlights

WHOI scientists and engineers are at the forefront of ocean science and technology, seeking answers to pressing questions about our global ocean and educating the next generation of ocean leaders through programs including the renowned MIT-WHOI Joint Program. WHOI scientists and students use world-class ships, advanced marine robotics and submersibles, and innovative research methods to understand the ocean and climate, to support ocean stewardship and sustainability, and to shed light on the ocean's impacts on human health and well-being. Here are some highlights from 2018.

VISITING THE SHADOWY, UNEXPLORED OCEAN TWILIGHT ZONE

The area of the ocean where the last of the sun's rays reach the deep sea has long been a mystery to scientists. This mid-layer, called the mesopelagic zone, is thought to be home to the world's largest mass of fish and is one of the ocean's most productive regions. WHOI embarked on a project to study life in this murky frontier with deep-sea submersibles and new robots designed to submerge thousands of feet beneath the ocean's surface. One of these instruments is a 16-foot vehicle called *Deep-See* equipped with cameras, acoustic and chemical sensors to capture 3-D images of plankton, photograph jellyfish, and collect DNA samples.

EXPLAINING THE VARIATION IN SEA LEVEL RISE ALONG THE EAST COAST

Geologic remnants of the last Ice Age have caused some areas along the East Coast to experience more extreme sea level rise than others—with communities along the Chesapeake Bay seeing a foot and a half of sea level rise over the last century while shorelines along the Gulf of Maine have risen by only half a foot over the same period. To study this variability, oceanographers at WHOI collaborated with researchers at Harvard University to combine observational data along the Atlantic coast with geophysical models. Their work provides a more complete view of sea level change since the beginning of the 20th century and can better predict how coastlines will continue to shift.

Photo by Paul Caiger, WHOI

Photo by Sarah Das, WHOI

Photo by Tom Kleindinst, WHOI

MIT-WHOI JOINT PROGRAM IN OCEANOGRAPHY/APPLIED OCEAN SCIENCE & ENGINEERING TURNS 50, RECEIVES GENEROUS GIFTS

The MIT-WHOI Joint Program welcomed its fiftieth matriculating class in 2018 (see accompanying article), with 32 students, up from 24 in 2017, and including six masters students from the U.S. Navy. In December the Navy conducted a curriculum review of the Joint Program, and committed to sending at least six students per year. In November, WHOI received a gift of $1 million from Delle Maxwell and Pat Hanrahan to the Arthur E. Maxwell Fellowship Fund, established by Dr. James A. Austin. Delle and Pat made another gift of $1.5M in honor of Arthur E. Maxwell to MIT to support Joint Program activities.

NEW TECHNOLOGY COULD COMBAT RED TIDE

Millions of dead fish and hundreds of poisoned sea turtles, manatees, and dolphins washed up on Florida's beaches throughout 2018 in one of the worst red tide blooms in a decade. In the midst of the environmental catastrophe, WHOI biologists conducted lab experiments and field studies to control the noxious blooms using clay particles that bind to the algae cells and sink to the seafloor. Separately, the NOAA Sea Grant program provided funding for researchers to monitor harmful algal blooms using robotic sensors. The grant builds on monitoring projects throughout the world, from disease-causing algae in Caribbean reef fish to shellfish poisoning in New England and new algal toxins appearing in the Arctic.

ICE MELT SHAKES UP ARCTIC FOOD WEB

WHOI chemists aboard the icebreaker *Healy* found the chemical makeup of the ocean near the North Pole has radically changed in the last decade. Levels of radium isotopes doubled in the Arctic Ocean since 2007, indicating that more carbon and other chemicals have entered the waters. Scientists expect plankton to prosper with the greater availability of nutrients, reverberating across the Arctic food web to affect populations of whales, seabirds and fish. The research is part of an ongoing WHOI project to monitor seawater chemistry in the Arctic.

WHOI WELCOMES 58 POSTDOCTORAL SCHOLARS, FELLOWS AND INVESTIGATORS

In 2018, WHOI welcomed 20 Postdoctoral Scholars (awarded competitively and funded using endowed funds designated for this purpose, as well as scholarship awards from other sources); 10 Postdoctoral Fellows (funded through competitive awards from external agencies, foundations, and foreign countries); and 28 Postdoctoral Investigators (funded by grants from external funding sources that are part of the research base in each department).

PILOT WHALE FAMILIES HAVE THEIR OWN DIALECTS

WHOI ecologists working in Hawai'i discovered that short-finned pilot whales travel together in family groups, each with their own distinct set of calls. The scientists relied on 15 years of data from recordings, photographs, and genetic samples for the study. They suspect that different dialects help individual pilot whales identify their clan when they come into contact with other pods. These language differences provide new insights into the whales' strong social ties and could help assess their genetic diversity. And ultimately the ability to identify family groups of pilot whales by sound could inform conservation strategies for the species.

GREAT WHITE SHARKS FEAST IN THE DEEP OCEAN

Great white sharks face a dilemma in the open ocean: their most plentiful source of food resides hundreds of feet below the surface in the ocean twilight zone, but those depths aren't warm enough to sustain the animals' body temperatures. By tagging two adult great whites, researchers at WHOI and the University of Washington discovered the sharks' trick to reach the distant feast. Great whites cruise on warm-water eddies, swirling pockets of water tens of miles across that carry the sharks down to colder depths. Scientists suspect that other shark species also rely on the twilight zone to feed, suggesting the warm ocean currents could be vital to the survival of many large ocean predators.

ARTHUR VINING DAVIS FOUNDATIONS FUND EXPANSION OF WHOI UNDERGRADUATE PROGRAM

WHOI received a grant from the Arthur Vining Davis Foundations to expand the Semester at WHOI (SAW) Program, a semester-long, tuition-supported undergraduate program that includes a for-credit research project and the opportunity to take oceanography courses alongside graduate students. The grant provides funding to increase publicity, develop contacts with undergraduate institutions, and use tuition-matching funds to provide scholarships.

GREENLAND'S MELTING HAS KICKED INTO OVERDRIVE

WHOI researchers climbed thousands of feet to the top of the Greenland ice sheet to take ice cores with an instrument the size of a traffic light. Their data revealed that Greenland's ice sheet is melting at a faster rate than any time in its recorded history—in the last 350 years, if not millennia. Melting from Greenland's ice sheet, the second largest in the world, is a major driver of global sea level rise as it inundates oceans with trillions of tons of runoff from snow and ice in recent decades. Researchers say the melting will only ramp up as global temperatures continue to climb.

SUMMER STUDENT FELLOWSHIP PROGRAM RECEIVES NSF FUNDING, GROOMS FUTURE OCEANOGRAPHERS

The Summer Student Fellowship (SSF) Program class of 2018 included 33 undergrads—one from the U.S. Naval Academy. Additionally, the NSF-sponsored Research Experience for Undergraduates (REU) Program funded a proposal to continue support for 10 SSF students per year.

MAPPING MICROPLASTICS IN THE OCEAN

Most of the eight million tons of plastic in the ocean is in tiny pieces nearly invisible to the naked eye. Researchers at WHOI are embarking on a long-term, interdisciplinary investigation of marine microplastics to understand the fate of these particles drifting through the ocean, gauge their impacts on marine life and human health, and engineer new technology solutions needed to push the science forward.

NEW INSIGHT FOR OIL SPILL CLEANUPS

Oil spill response plans have relied on chemical dispersants to prevent the worst damage to shoreline ecosystems. But WHOI scientists and Environmental Protection Agency officials studying the 2010 Deepwater Horizon spill found that chemical dispersants are far less effective after oil has been exposed to sunlight than previously assumed. The sun initiates photochemical reactions that effectively weather oil particles, limiting dispersant's ability to breakdown slicks into droplets. Scientists also simulated weather conditions from the Deepwater Horizon spill, demonstrating that the majority of dispersant applications would have been ineffective. The study shows that oil spill responders have a fleeting window to use chemical dispersants and highlights a need to reassess guidelines for oil spill cleanup efforts going forward.

DISCOVERING A HIDDEN SUPER-COLONY OF PENGUINS

A WHOI expedition to Antarctica's Danger Islands revealed one of the largest gatherings of Adélie penguins in the world—two colonies made up of over 1.5 million birds, the third and fourth largest colonies

recorded. Scientists had no idea the islands were such important breeding grounds for the penguins and only went to search the area after seeing hints of a large population on satellite imagery. When the research team reached the remote archipelago off the northern tip of the Antarctic Peninsula, they used ground counts and drone photographs to estimate the colony size. While many Adélie populations throughout Antarctica have been declining, the colonies on the Danger Islands appear to be healthy. The discovery strengthens the case to provide ecological protections for the area under proposed international treaties.

TRACKING HURRICANE STRENGTH IN REAL TIME

As Hurricane Florence bore down on the east coast of the U.S. in September, researchers at WHOI monitored the temperature and salinity of the water in its path to help forecasters better predict the storm's direction and intensity. From the sea, an autonomous vehicle tracked changes in the temperature, salinity and velocity of the upper 3,000 feet of the ocean and relayed the measurements over satellite, as part of an ongoing WHOI project to monitor the Gulf Stream. At the same time, scientists working with the U.S. Air Force journeyed to the storm by airplane and dropped newly developed floats to record measurements from the water column on the outskirts of the storm.

GEOLOGISTS RECONSTRUCT ENORMOUS UNDERWATER VOLCANIC ERUPTION

WHOI researchers investigated the remnants of a massive underwater volcanic eruption off the coast of New Zealand, thought to be the largest of its type ever recorded. Two underwater robots, the autonomous underwater vehicle *Sentry* and the remotely operated vehicle *Jason*, conducted 33 dives to inspect the inside of the volcano's crater. *Jason* brought up samples of erupted material made up of lava, ash and pumice from nearly a mile beneath the ocean's surface. The expedition found that the eruption was far larger than the 1980 eruption of Mount St. Helens, occurring along 14 deep-sea volcanic vents that spit out chunks of rock the size of minivans.

A NEW WAY TO TRACK OIL SPILLS UNDER SEA ICE

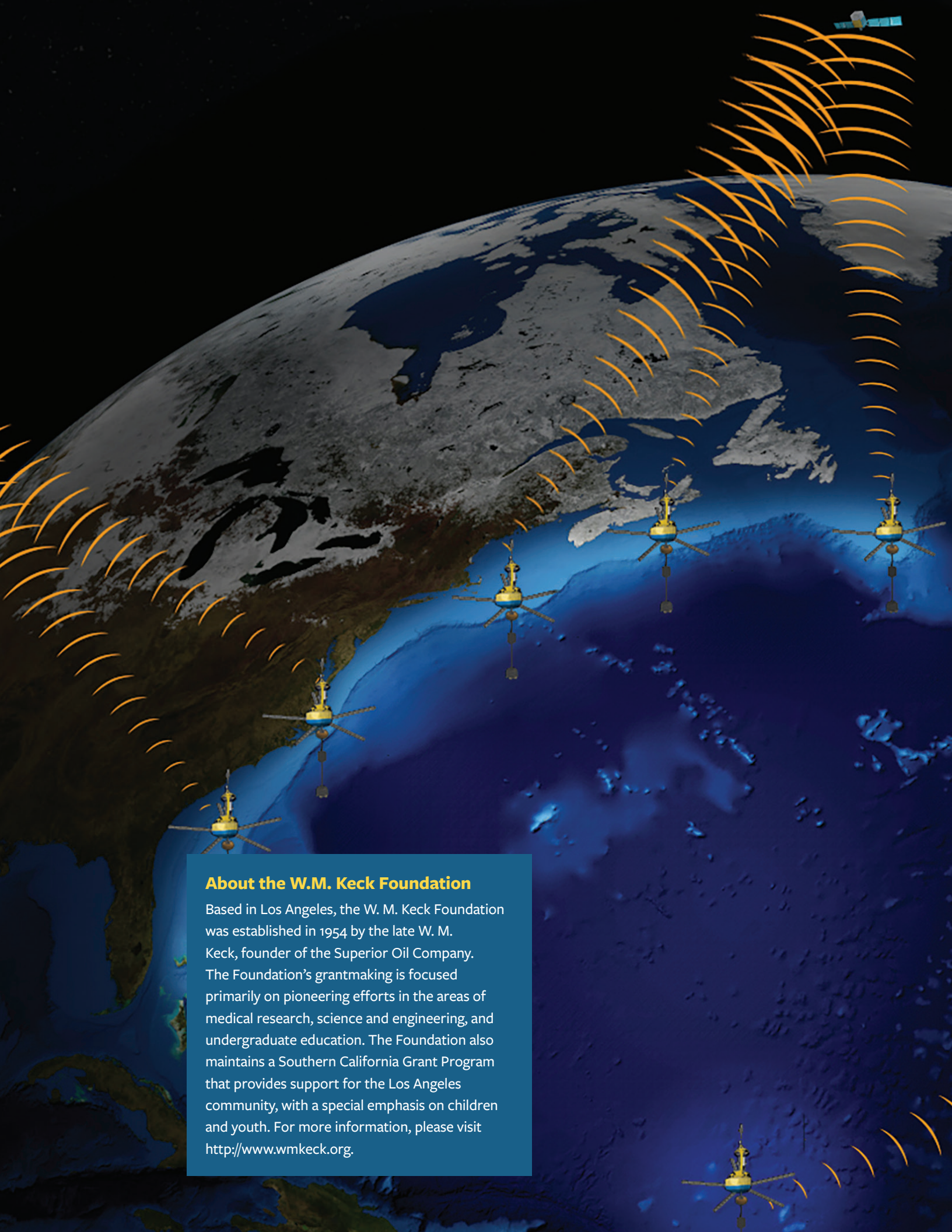
The risk of an oil spill at high latitudes is particularly hazardous because of the chance of a leak beneath sea ice, where a spill is entirely hidden from onlookers. WHOI engineers have worked to mitigate this threat by developing a robot called a Long Range Autonomous Underwater Vehicle that can swim for nearly 400 miles beneath sea ice to locate oil, map where it's flowing, and relay the information in real time. Coast Guard officials responding to a spill could deploy the robot into open water from shore, ship, or helicopter. Responders could also use the technology in temperate waters to track deep or far-reaching spills.

HUMAN ACTIVITY ALONG THE MISSISSIPPI RIVER HAS CAUSED MORE EXTREME FLOODING

Researchers traced the history of flooding on the Mississippi River back over 500 years to understand how efforts to build artificial levees along the river have influenced the region's flood events. The scientists found that engineering projects on the river since the 1920s have exacerbated natural variations in flood cycles, leading to a dramatic rise in extreme flooding in the last century. The work utilized a coring technique to sample sediment from lake bottoms pioneered by WHOI paleoclimate scientists to track the history of hurricanes.

ENDOWMENT SUPPORTS SECOND JOINT PROGRAM STUDENT CRUISE ABOARD R/V *NEIL ARMSTRONG*

The second Joint Program student cruise on R/V *Neil Armstrong* took place in November 2018 thanks to the *Armstrong* Endowment Fund that supports WHOI's cost-share for the ship. With their faculty mentors Glen Gawarkiewicz and Joel Llopiz, twenty students gained invaluable experience planning and organizing the three-day, two-night expedition to the edge of the continental shelf, where they discovered signs of water from the Gulf of Maine intruding into the shelfbreak front south of Martha's Vineyard.



About the W.M. Keck Foundation

Based in Los Angeles, the W. M. Keck Foundation was established in 1954 by the late W. M. Keck, founder of the Superior Oil Company. The Foundation's grantmaking is focused primarily on pioneering efforts in the areas of medical research, science and engineering, and undergraduate education. The Foundation also maintains a Southern California Grant Program that provides support for the Los Angeles community, with a special emphasis on children and youth. For more information, please visit http://www.wmkeck.org.

Coming Soon: A New Ocean "View"

The invention and evolution of the telescope has literally opened the world's eyes to the universe and revealed remarkable new findings, including the geography and weather of the planets in our solar system, new stars, planets and asteroids beyond our galaxy, and contributed to our knowledge of gravity and the fundamental laws of the physical world.

Now, thanks to a visionary $1 million grant from the W.M. Keck Foundation, WHOI scientists could make a similar impact on the ocean universe, by building the first-ever real time 3D acoustic underwater "telescope." This remarkable innovation has the potential to provide an unprecedented view of what lies within—by enabling researchers to use sound to map and study the ocean. Keck is a major supporter of pioneering science and engineering, including telescopes, and a long-time supporter of innovation at WHOI.

Why not use a regular telescope? "Seawater quickly absorbs or scatters light, radio waves, and other forms of electromagnetic radiation, making conventional telescopes useless beneath the ocean surface," says the telescope's inventor Ying-Tsong "Y.T." Lin, an associate scientist in WHOI's Applied Ocean Physics and Engineering Department. But sound travels far through the ocean and just as marine mammals evolved to use sound to communicate, find food, and navigate underwater, scientists are now using sound to observe and probe the depths.

"The ocean is almost entirely opaque to humans," says WHOI President and Director Mark Abbott. "This new innovation is a critical step toward developing a detailed understanding of the marine environment."

The underwater acoustic telescope promises to provide direct observation of phenomena including waves and rainfall that produce telltale acoustic signatures at the sea surface, to marine mammals and fish in the midwaters to earthquakes at the seafloor.

"We are fortunate to have the support of the Keck Foundation in designing and building the acoustic telescope," said Lin. "With this new tool, we can assemble an eye-opening acoustic picture of our ocean with untold potential for expanding our knowledge."

Illustration by Natalie Renier, WHOI

In Memoriam

Lisina Hoch - An Outstanding Supporter of Oceanographic Research

Woods hole oceanographic institution lost a lovely friend, a devoted leader, and an avid supporter when former Trustee and Life Trustee, Lisina M. Hoch, passed away early this year at age 89.

Lisina was an adventurer and an ocean lover. She was a member of the Explorers Club, who traveled extensively to far-flung locations such as the Galápagos, the Himalayas, and Bhutan. She spent summers by the sea in her home on Martha's Vineyard and enjoyed her membership at the Edgartown Yacht Club.

Lisina is widely remembered for her philanthropic leadership and at WHOI that is especially true. Together with her husband Frank, she became a WHOI Associate in 1983. She then became a Member of the Corporation in 1996, a Trustee in 1998, a Fye Society Member in 2003, and served as Life Trustee since 2000. Over the years, the Hochs introduced countless new friends to WHOI and helped to facilitate a wide variety of research by means of generous and innovative philanthropy to, among others, the Ocean Ventures Fund for graduate students, the Jason Project, the Doherty Postdoctoral Scholarship Fund, the Director's Discretionary Fund, the Scientific Staff Mentorship Program, the Charles D. Hollister Fund for Innovative Research, and their own endowed fund for crucial early career support of assistant scientists. The Hochs also provided support for the 2011-2013 upgrade of the Alvin submersible and for the R/V Neil Armstrong Endowment.

In recognition of their tireless advocacy and creative efforts to stimulate private and leveraged support for basic research, WHOI awarded Lisina and Frank its Cecil H. Green Award in 2003. The award honors individuals who have made outstanding contributions to oceanographic research at WHOI.

"Lisina has left an extraordinary legacy for ocean science at WHOI," said President and Director Mark Abbott. "We miss her leadership, her generosity, and her adventurous spirit. We are fortunate that Lisina's son Steven, a WHOI Trustee, and her daughter Daphne, a WHOI Corporation member, are carrying forward her dedication to the ocean and philanthropy."

"Lisina has left an extraordinary legacy for ocean science at WHOI."

—WHOI PRESIDENT AND DIRECTOR MARK ABBOTT

Photo by Shelley Dawicki, WHOI

ALVIN
OODS HOLE
ANOGRAPHIC
STITUTION
WOODS HOLE OCEANO
1930

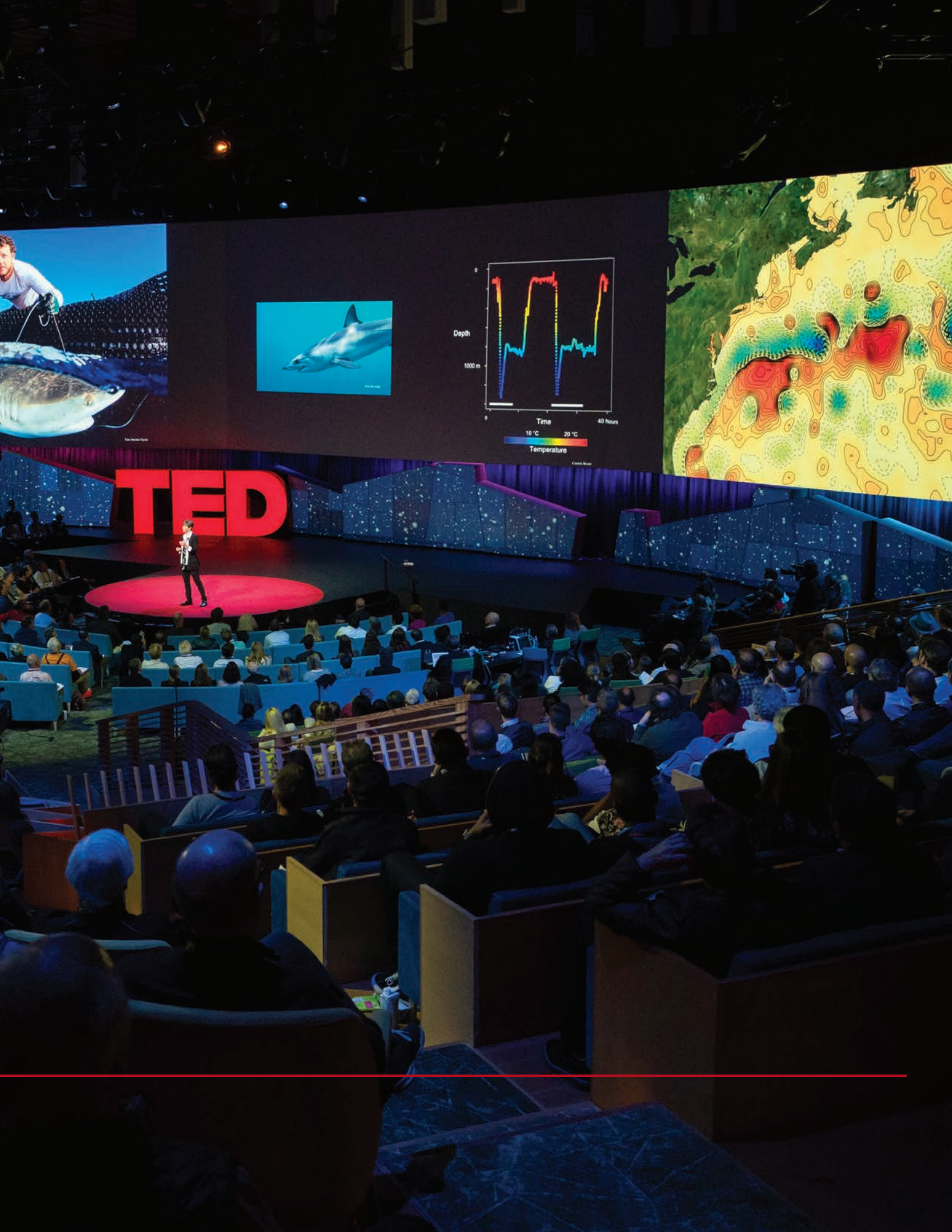
FOCUS ON PHILANTHROPY

A New Paradigm for Funding Ocean Science

The Audacious Project funding inspires bold advances at WHOI with global impact

By Véronique LaCapra

Shedding light on a dark region—WHOI biologist and Ocean Twilight Zone project team co-lead Heidi Sosik speaks at the TED conference in Vancouver in 2018. Photo by Jason Redmond, TED


Depth
0
1000 m
Time
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40 hours
10 °C
20 °C
Temperature
TED

Woods Hole Oceanographic Institution is embarking on a journey to explore and understand one of our planet's last hidden frontiers—the ocean twilight zone (OTZ), a shadowy region far below the ocean's sunlit surface. The OTZ project is WHOI's first major research initiative supported by a new, disruptive funding model: The Audacious Project.

Watch Heidi Sosik at TED
twilightzone.whoi.edu/TED

Housed at TED, The Audacious Project matches up philanthropic organizations and individuals with highly innovative projects designed to inspire large-scale positive change. In the spring of 2018, The Audacious Project chose the OTZ team as one of its first awardees, connecting WHOI with donors who provided a total of $35 million in support—the largest philanthropic gift in the Oceanographic's history.

One early benefit of Audacious funding was the opportunity for OTZ project leader Heidi Sosik to deliver a TED Talk at the 2018 TED conference in Vancouver, putting WHOI ocean science on the world stage.

"It's hard to imagine a more important pursuit of vital knowledge than a deep dive into the twilight zone," said TED Curator and The Audacious Project lead Chris Anderson. "The ambition and potential of this WHOI initiative are equally thrilling. We are truly proud and excited to see this become one of the major initiatives catalyzed by The Audacious Project."

Most of the seven world-changing ideas awarded Audacious funding in 2018 are led by social entrepreneurs. WHOI's is the only one focused on ocean science.

"Through Audacious we have a coalition of funders supporting some of the world's most bold and actionable projects," said Anna Verghese, Executive Director of The Audacious Project. "WHOI is poised to effect wide-scale change and promote unprecedented engagement in ocean science, opening up twilight zone research expeditions, technology innovations, and scientific discoveries to the public in a whole new way."

Bridgewater Associates founder Ray Dalio is a leading supporter of ocean exploration and media through his OceanX initiative, and he championed WHOI's Ocean Twilight Zone initiative in the competition for The Audacious Project funding.

"After eight years of working with WHOI on a number of major ocean exploration projects, I am thrilled to dive deep into the exploration of the twilight zone together," Dalio said. "We will explore this extraordinarily interesting area and bring this exploration to the attention of millions of people through a broad based social and traditional media effort."

WHOI board member Tom Tierney says he saw The Audacious Project as an opportunity to get WHOI science and technological innovation some well-deserved attention from potential funders and the general public.

"In my 22-year relationship with the Institution, I've come to know WHOI as a powerhouse of both ocean research and engineering, a unique combination that has led to some truly amazing advances in our understanding of the ocean," Tierney said. "Now is the time to aggressively step up our game, to communicate our impact on the world, and to make the case for boldly supporting our efforts."

Scientists have long studied shallow coastal waters, the sea surface, and even the ocean bottom—but still little is known about the ocean's midwater: the mysterious twilight zone. Robertson Foundation President Sir John Hood says that needs to change.

"It is remarkable that, in this area of exploration, such a massive and life-sustaining part of the ocean remains understudied," said Hood, whose foundation is providing critical funding for WHOI's OTZ project. "WHOI is pairing world-class oceanography with advanced technological development in its innovative bid to advance our understanding of the twilight zone's mysteries."

Terrifying but tiny—Projected on the TED stage screen behind WHOI biologist Heidi Sosik are the gaping jaws of a bristlemouth, a fish that dwells in the ocean twilight zone. Bristlemouths may look terrifying, but a dozen of these tiny fish could fit in the vial she holds in her left hand. Photo by Bret Hartman, TED.

Craig McCaw of The Craig and Susan McCaw Foundation hopes the project will profoundly increase the quality of research on the role of the twilight zone.

"It appears that it is probable the twilight zone is vastly more important to the health of our planet than anyone previously realized," McCaw said. "WHOI's OTZ project has the potential to provide critical knowledge to policymakers, in the hope they will prevent a global environmental catastrophe. We believe that WHOI is the organization best qualified to undertake this important work. I wish the team amazing success in this voyage of exploration."

Filmmaker and ocean explorer James Cameron has a long-standing partnership with WHOI, which he calls "the world's leading independent organization dedicated to deep-ocean research, exploration, and education." Cameron calls the ocean twilight zone "one of the last and most important remaining frontiers on Earth," and says the need for WHOI to take the lead in exploring it has never been more urgent.

"Commercial fisheries are already homing in on the twilight zone's abundant resources—when we still know so little about them or the food webs they support," Cameron said. "Those animals also play a key role in moving carbon to the deep ocean. Without them, more carbon dioxide will build up in the atmosphere, warming the planet with potentially disastrous effects."

Time is of the essence, agrees Tony James, a major supporter of WHOI's OTZ initiative.

"We need to act now, and act quickly," James said. "With so much biological abundance, the twilight zone represents a juicy, yet vulnerable, target. Its resources could either help sustain growing human populations—or rapidly disappear from overexploitation. WHOI has the scientific expertise to develop the data that enable policymakers to protect this essential part of the ocean, today and for future generations."

The Audacious Project's philanthropic model of research funding will enable scientists to get more information, more quickly—giving all of us a chance to better understand, appreciate, and protect the ocean twilight zone before it's too late.

OUR AUDACIOUS SUPPORTERS

Woods Hole Oceanographic Institution is grateful for the remarkable generosity and vision of the foundations and individuals who are making science and exploration in the ocean twilight zone a reality through their support of The Audacious Project.

- The Dalio Foundation
- The James Family
- The Craig and Susan McCaw Foundation
- The Robertson Foundation
- Anonymous (2)

The Power of Unrestricted Giving

Gifts of flexible, discretionary funding to Woods Hole Oceanographic Institution are powerful investments for advancing innovation and unleashing WHOI scientists to pursue bold new lines of research and exploration that are vital to understanding our changing ocean.

Unrestricted support comes from generous visionary foundations and generous individuals, including those who choose to make a planned gift to WHOI. Gifts of this kind empower WHOI to promote new discoveries, respond nimbly to societal challenges, and enable WHOI scientists and students to learn the impossible by doing the impossible. Unrestricted gifts also help us leverage future funding, thereby having a powerful multiplier effect.

Here are some of the supporters who gave unrestricted gifts in support of ocean research, education and exploration in 2018.

ROBIN POWELL MANDJES TURNS A PASSING GLIMPSE OF WHOI INTO DEVOTED LEADERSHIP AND SUPPORT

Robin Powell Mandjes and her husband Lucas own a summer home on Martha's Vineyard just off of Woods Hole, Mass. But, for years, they barely noticed that they were passing by Woods Hole Oceanographic on their way to catch the ferry. Once Robin learned about WHOI and its reputation as a world-class ocean research organization, she decided to get involved. These days, Robin is a devoted Trustee who is also an ambassador, fundraiser, and annual fund supporter. "Every one of us relies heavily on the ocean for so much," she says. "I'm proud to help lead and support WHOI's amazing scientists and engineers as they strive to explore and learn more."

MARIE AND HAROLD "JOE" DOEBLER'S CHARITABLE GIFT ANNUITIES CARRY FORWARD A FAMILY LEGACY

Joe Doebler's decision to make an investment in a charitable gift annuity with WHOI was easy, he says. It was the same decision his wife, Marie, had made in 2010. "I am receiving more income from the

WHOI Trustee and supporter Robin Powell Mandjes.

Photo by Tom Kleindinst, WHOI

Marie and Harold "Joe" Doebler are supporting WHOI with their charitable gift annuities.

Photo by Jim Flynn, WHOI

investment than I had beforehand, and I know that after I'm gone, the money will do great things for ocean science," says Joe. He and Marie have long-time WHOI ties. Her father, Columbus O'Donnell Iselin, was the Institution's director from 1940 to 1950 and from 1956 to 1958. "Our charitable gift annuities are a great way to carry forward his legacy," says Marie.

THE G. UNGER VETLESEN FOUNDATION FUNDS MYRIAD RESEARCH PROJECTS AND PEOPLE

A $750,000 gift from Vetlesen Foundation supported groundbreaking research by scientists, students, and postdocs, including projects focused on: understanding hurricanes, managing saltmarsh ecosystems, preventing whale ship strikes and entanglements, large whales as indicators of ecosystem health, the effects of climate change on penguins and marine life, exploring the twilight zone, measuring marine snow, making fuel from farmed seaweed, observing the ocean's interrelated systems, and climate-change-resistant coral reefs (aka super reefs). The Vetlesen Foundation provides support for Earth science institutions of excellence. It was created in 1955 and named for Georg Unger Vetlesen, a Norwegian who loved the sea. Vetlesen was in the shipbuilding business for many years and later served as president and chairman of the U.S. Company representing the Norwegian American Line. He was also founder and chairman of the board of Scandinavian Airlines System, Inc., which began transatlantic operations in 1946. The Vetlesen Foundation has provided WHOI a total of $20.1 million in support since 1987. "We are delighted to support the scientific achievements of WHOI, which helps provide a clearer understanding of the Earth, its history, and its relation to the universe," said Ambrose Monell, Vetlesen Foundation President.

The G. Unger Vetlesen Foundation Board: Maurizio Morello, Gary Beauchamp and Ambrose Monell.

Photo courtesy of the Vetlesen Foundation.

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It is a privilege to acknowledge the many individuals, foundations, corporations, and organizations that made gifts or pledges in 2018.

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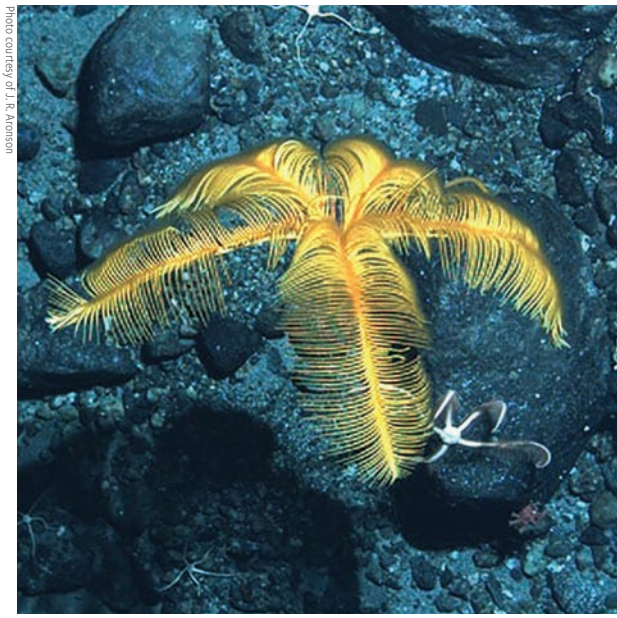

Photo courtesy of J. R. Aronson

Stars and Stripes

A golden feather star raises its arms to feed. Behind, brittle stars are perched across the boulder-field.

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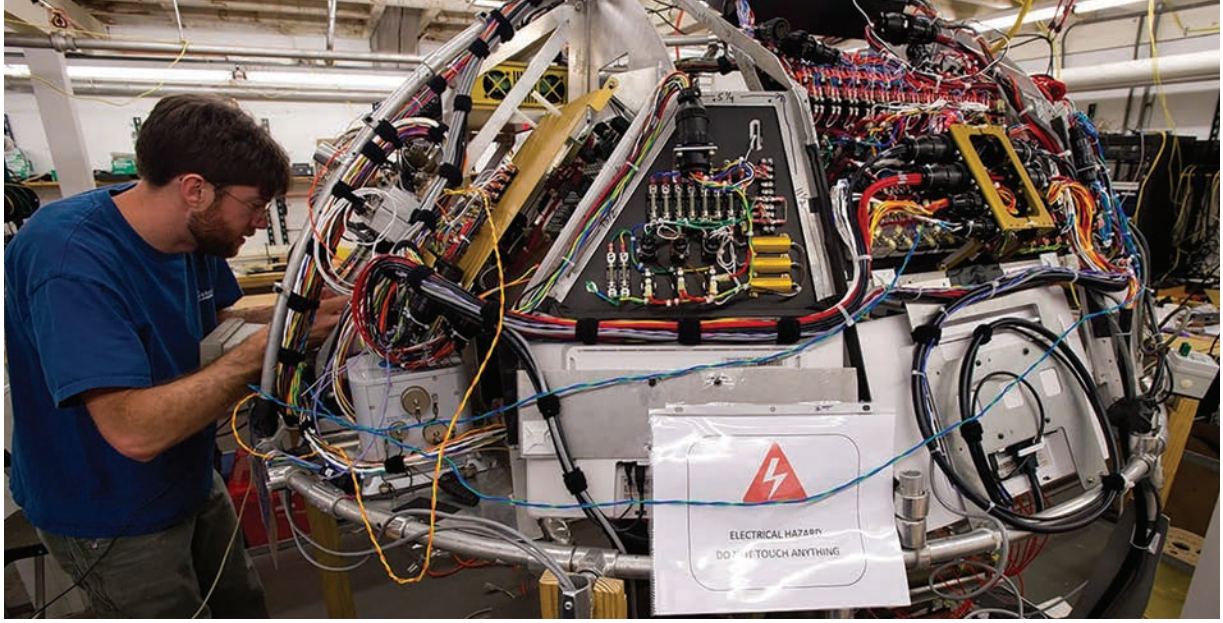

Photo by Tom Kleindinst, WHOI

Working on the Birdcage

Chris Lathan, a former pilot of the human-occupied submersible *Alvin*, works during the sub's upgrade that was completed in 2014, fifty years after the original *Alvin* was launched. He's working on the "birdcage," a mockup of the equivalent scaffold in the real *Alvin* that supports all the systems that distribute power, data, audio, and video to the interior of *Alvin's* personnel sphere. Working on the birdcage, Lathan could design and troubleshoot the systems before they were incorporated into the upgraded sub. *Alvin* is still going strong and recently completed its 5,000th dive.

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Portrait of a Penguin

This Adélie penguin was recently examined as part of a 55-year-long study of this species on Ross Island in Antarctica.

Photo by Chris Linder, WHOI

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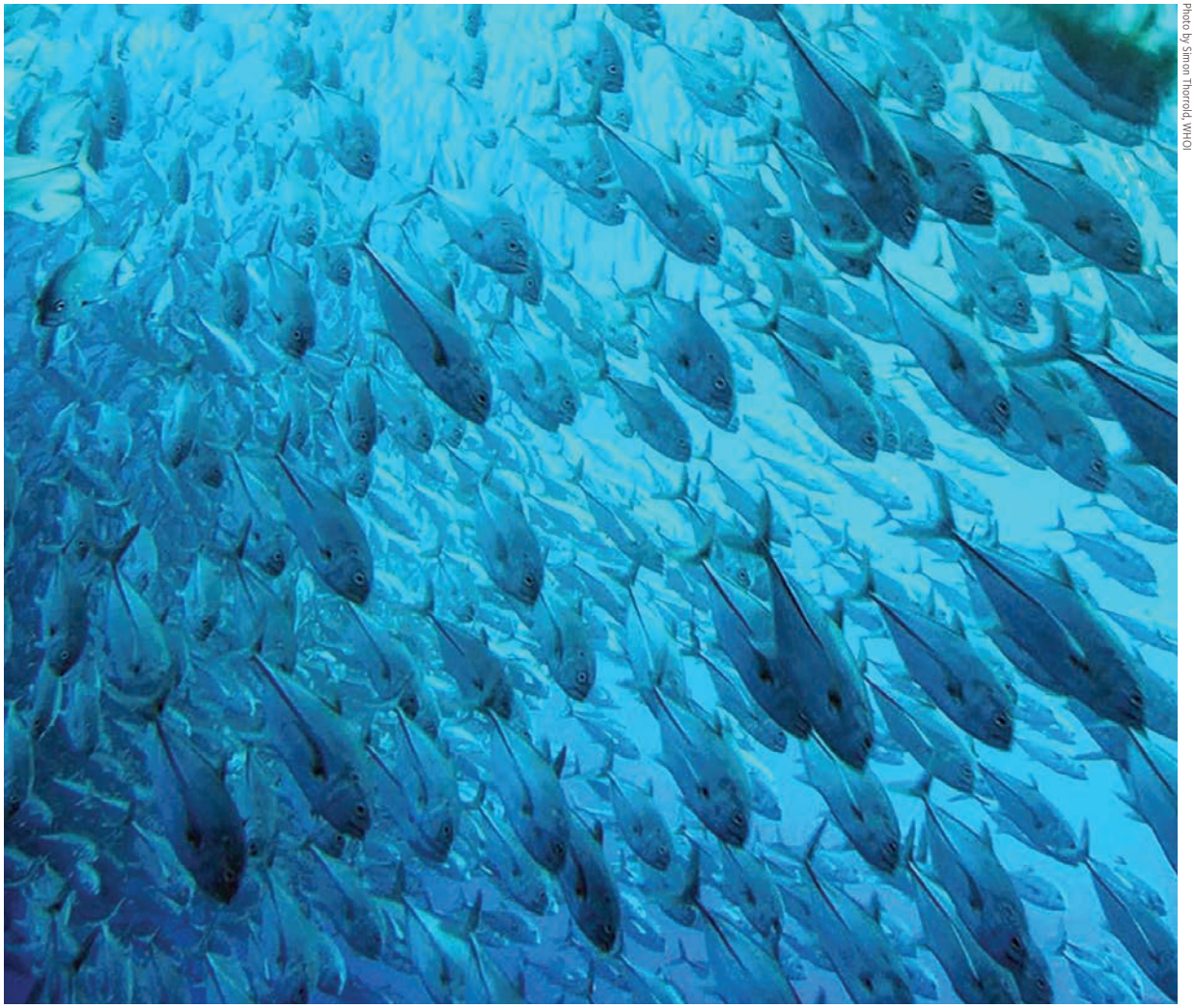
A Splash In the Dark

The human-occupied submersible *Alvin* isn't often recovered after dark—usually it's on deck in time for dinner, even though the sub holds enough oxygen, food, and water for the pilot and two observers to stay submerged for nearly four days, if necessary. On an expedition to the hydrothermal vents on the East Pacific Rise at 9°50'N, however, the sub got in the water later than expected, so rather than cut the dive short, the science and *Alvin* teams decided to come up after sunset, which made for a dramatic and picturesque recovery.

Photo by Jason Sylvan, WHOI

Bigeye Travally

A large school of bigeye trevally swims past a submarine carrying WHOI scientists descending in Cabo Pulmo National Park on the east coast of Mexico's Baja California Peninsula. Overfishing had decimated pelagic and reef fishes here, but populations have returned after a marine reserve was established in 2005.



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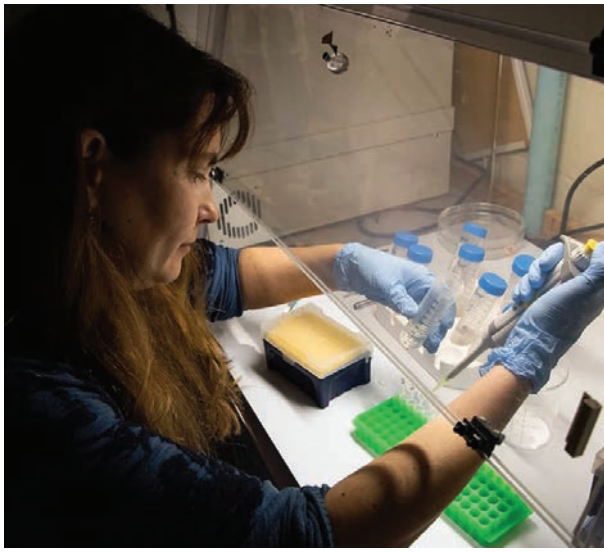

Photo by Tom Kleindinst, WHOI

DNA Detective

Genetic material in seawater provides WHOI biologist Annette Govindarajan with clues to investigate species in the ocean twilight zone.

Photo by Nick Mathews, Bermuda Institute of Ocean Sciences

Knee-Deep

WHOI engineer Chris Basque deploys instruments for the Ocean Observatories Initiative (OOI) Global Array as waves crash board the R/V *Nathaniel B. Palmer*. The array is laden with instruments that remain at sea for a year, silently collecting ocean measurements and beaming the data back to researchers.

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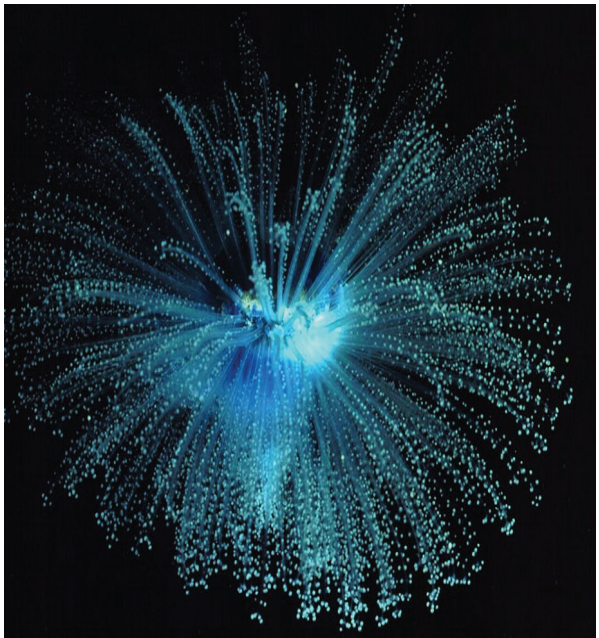

Photo courtesy of J. R. Aronson

Marine Fireworks

A siphonophore, which is closely related to the medusae. These animals are made up of multiple units, each specialized for a function like swimming, feeding, or reproduction. This "modular" construction allows some siphonophores to grow very large, over 100 feet long in the deep ocean.

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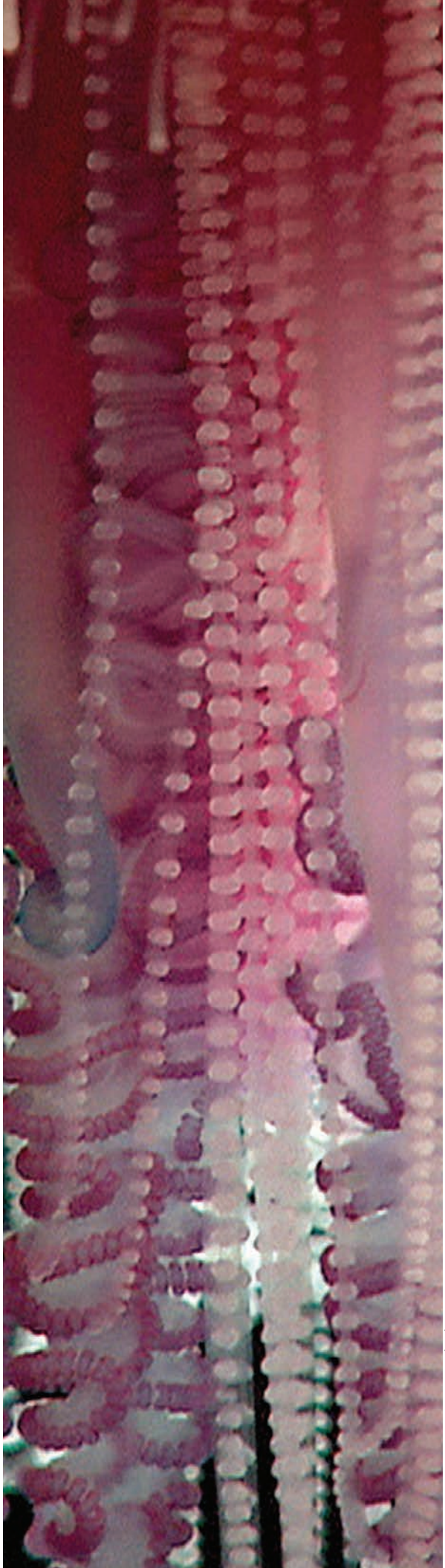

Photo by Larry Madin, WHOI

Beads that Sting

These may look like a curtain of Mardi Gras beads hung in a doorway, but they are actually Man-o'-War tentacles that can inject toxins into any creature unlucky enough to bump into them.

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Bequests in 2018

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Sub Checks

Alvin pilot Danik Forsman prepares the human-occupied submersible to make its first dive of an expedition to explore the geology and geochemistry of a chain of volcanic seamounts at 8° 20′ N near the East Pacific Rise.

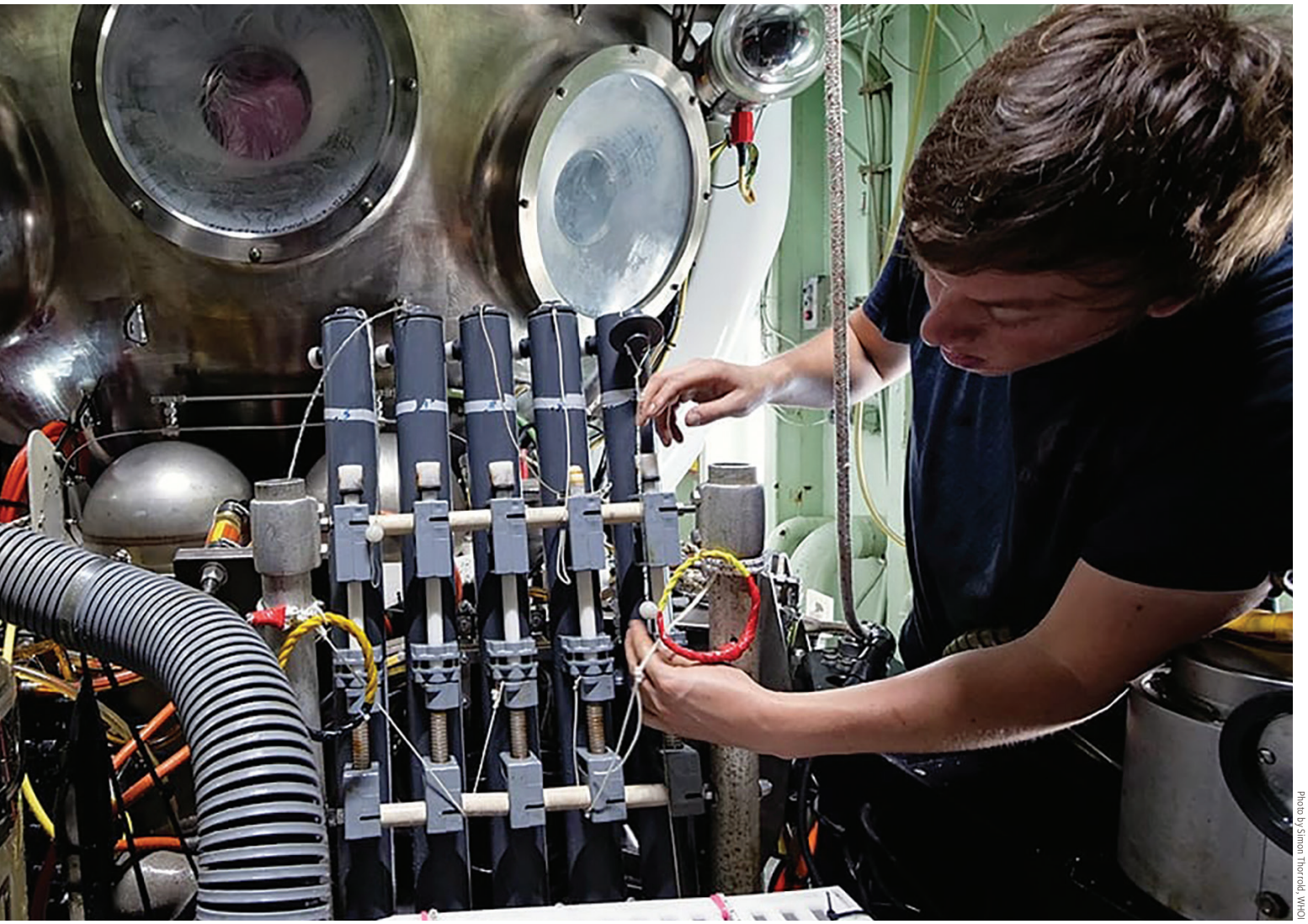

Photo by Simon Thorrold, WHOI

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The Woods Hole Oceanographic Institution is privileged to recognize members of the Paul M. Fye Society, which honors individuals who support the financial stability of the Institution through charitable bequests and life income gifts.

The Society is named for former Director Paul M. Fye, whose leadership and vision helped build the foundation that will support ocean science and education well into the future.

For information on gifts that provide income and tax benefits, contact Jim Flynn, Director of Major Gifts and Planned Giving, (508) 289-2018 or jflynn@whoi.edu.

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Photo by Kent Shreasley, WHOI

Armstrong in Southern Greenland

During a transit through the Prince Christian Sound in southern Greenland, the crew of the research vessel *Neil Armstrong* took advantage of calm conditions during an otherwise storm-tossed spring to work on deck in the strait's narrow waters.

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Photo by Sarah Das, WHOI

On Top of the World

Freshly drilled ice cores are taken from the 2,000-meter-high summit of an ice cap in Greenland. "There was a mix of excitement to learn what secrets the cores held about climate change, and nervousness about our precious samples flying away," said WHOI associate scientist Sarah Das, who led the expedition.

2018 Financial Statements

We are pleased to present the 2018 audited financial statements of the Woods Hole Oceanographic Institution (WHOI) and are grateful to our many funders, both private and federal, for their support of WHOI's mission of ocean research, exploration, and education.

Despite continued pressure on federal science budgets, significant Institutional financial and operational goals have been met, such as balancing the unrestricted budget, full pay down of our line of credit balance, the continuation of our "Investment in Science Program," as well as additional investments in reinforcing the overall capability of WHOI staff. Even as the uncertain federal funding outlook continues, our total funded Sponsored Research increased by 6% vs. last year, mainly due to increased funding from the National Science Foundation. In addition, WHOI has undergone a "Strategic Facilities Assessment" and is undertaking the construction of new facilities to allow for the expansion of sponsor-funded projects. Our work on identifying and implementing significant efficiency initiatives is ongoing, with savings being captured in our annual budgeting process.

STATEMENT OF FINANCIAL POSITION

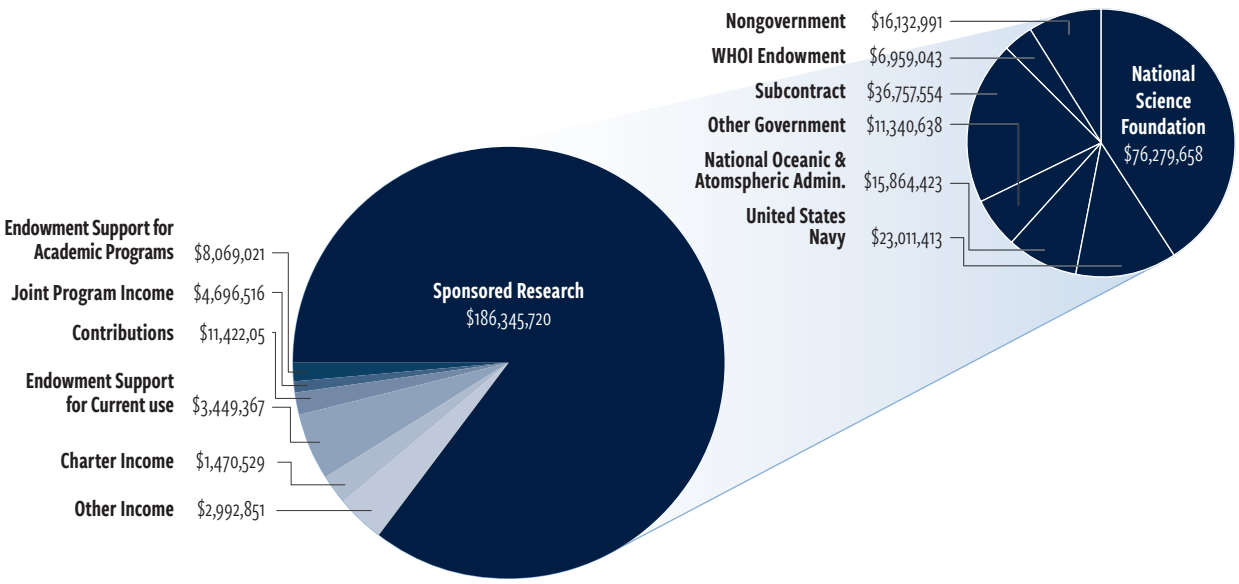
At December 31, 2018 WHOI's total assets were $608.1 million, total liabilities were $271.0 million and total net assets were $337.1 million.

Net assets represent the accumulated financial strength of a not-for-profit organization and are an important gauge of its ability to carry out its mission. The Institution issued $75.5 million in Mass Development Fixed Rate Revenue Bonds Series 2018, during 2018. The Institution received net proceeds of $86.3 million, of this amount $50.7 million was used to retire the Series 2008 Bonds, with the remaining amount to be used for future renovations and maintenance projects throughout the Institution along with building of new

Revenues

Total: $218,446,061

Sponsored Research Detail



facilities. The federal government allows interest and depreciation for real property and equipment in the Institution's overhead rates for reimbursement. Principal payments on the Series 2018 Bonds begin in 2019.

The endowment, $417.5 million, represents 68% of the total assets at December 31, 2018.

STATEMENT OF ACTIVITIES

WHOI's total operating revenues decreased by $4.0 million; from $227.6 million in 2017 to $223.6 million in 2018; and the Institution's change in net assets from operating activities was ($0.9) million.

$20.1 million of endowment income and appreciation was distributed to operations as follows:

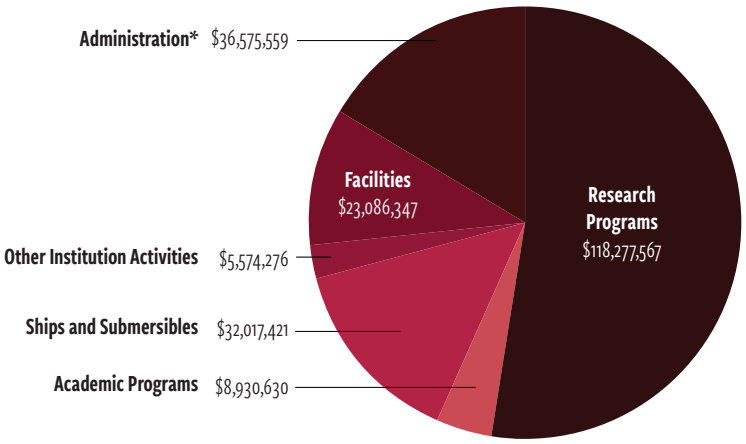
- Education $8.8 million
- Research $7.8 million
- Unrestricted $3.5 million

The Institution had Facilities and Administration costs of $59.7 million, and approximately 80% of that amount, $47.6 million, was recovered from the government and nongovernment research. This included $3.3 million of interest associated with the Series 2008 and 2018 Bonds. The remainder was Institutional expenses.

Philanthropy continues to play a larger role in meeting both the research and educational programming obligations. Current-use giving and endowment income accounted for 21% of the institution's revenue. FY18, saw a record number of donors with 2,945, which was a 19.4% increase over the previous year. The expansion of the donor base at all levels of giving is a key strategy for growth going forward.

Expenses

Total: $224,461,799



*About $12 million (unaudited) is direct administrative costs associated with science and engineering.

Summary

The Institution's commitment to understanding the ocean is stronger than ever; however, the federal funding environment continues to provide a challenge. WHOI continues to investigate expanding its sources of revenue by leveraging its industry recognized core skills in both the federal and industry marketplaces. In addition, WHOI continues to build on philanthropic giving as an essential part of our sustainable funding model for future engineering and science initiatives.

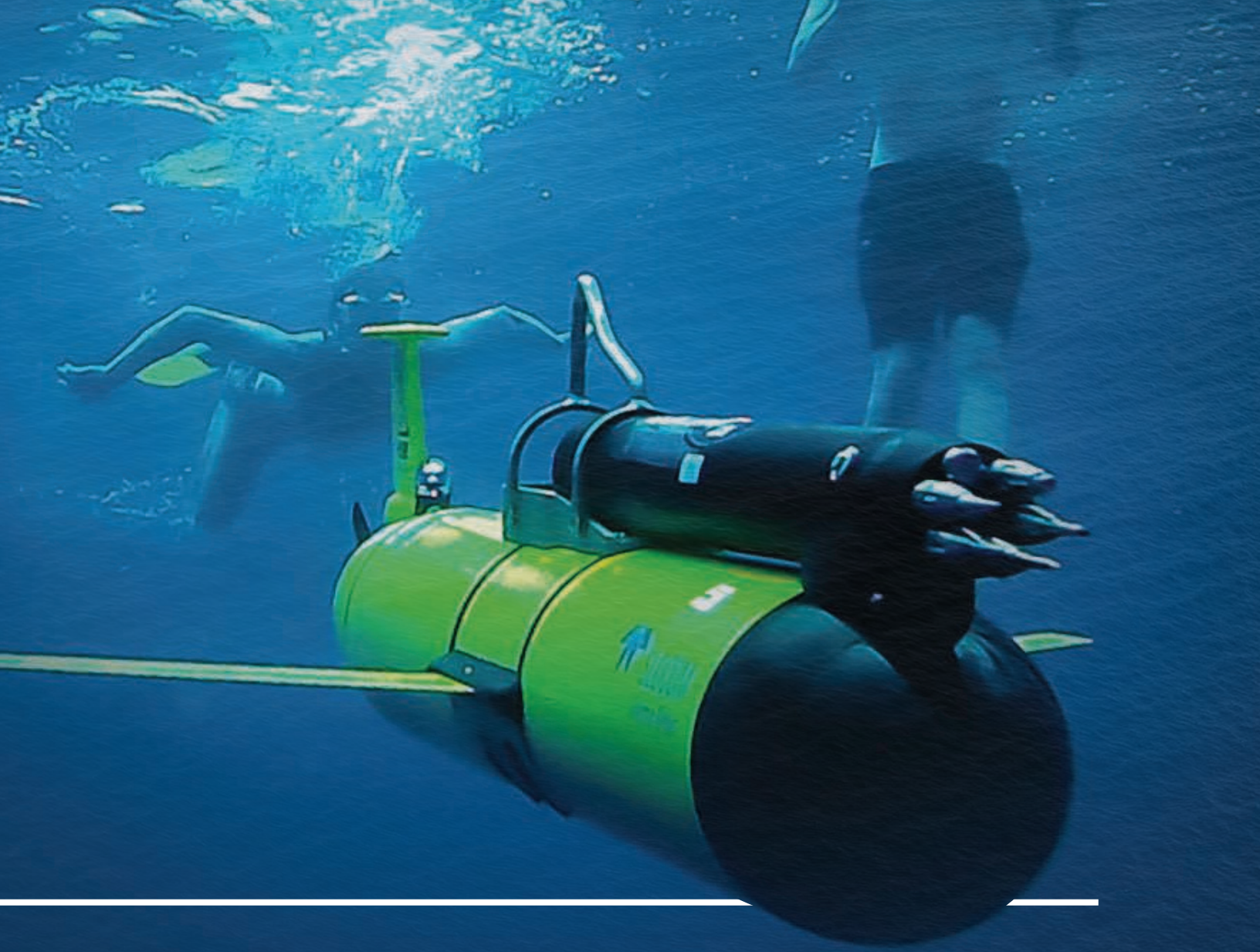
Get Involved. For the Ocean.

Make a Gift
Make an unrestricted gift in support of ocean research and exploration. You can donate online, by phone or mail. Checks can be mailed to our address below. Supporters who give over $1,000 annually receive a variety of benefits. Donate at www.whoi.edu

Donate a Home
Donate your vacation home or primary residence to WHOI and support the future of ocean science while receiving significant tax benefits. We'll guide you through the process. Learn more at: giving.whoi.edu/oceanhomes/

Make a Gift of Stock
Gifts of securities can make an immediate impact for both WHOI and you. And if the gift is made with appreciated securities, you will incur no capital gains tax. Visit giving.whoi.edu/ways-to-give/stock-gifts for details or contact Simion Procopenco, Cape Cod 5 Investment Services, 508-247-2120, or sprocopenco@infinexgroup.com

Consider a Planned Gift or Bequest
Create a lasting legacy by making a planned gift to support ocean research, exploration, and education while receiving financial and tax benefits. Planned giving donors are automatically inducted into the Paul M. Fye Society, the recognition society for those who have created a planned gift to help secure WHOI's future. Visit: giving.whoi.edu/ways-to-give/planned-giving/



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Contact Us

Attn: Development Department, MS #40
266 Woods Hole Road
Woods Hole, MA 02543
508-289-4895
www.giving.whoi.edu

Woods Hole Oceanographic Institution

Woods Hole Oceanographic Institution

266 Woods Hole Road
Woods Hole, MA 02543-1050

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