SCHMIDT OCEAN INSTITUTE

2017 ANNUAL REPORT

5 YEARS OF SCIENCE ABOARD *FALKOR*

Falkor explores off Nikumaroro Island, a remote, elongated, triangular coral atoll in the Phoenix Islands Protected Area. Well over one million viewers joined the livestreams from ROV SuBastian during the "Deep Corals of PIPA" research cruise.

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Falkor steams through the Pacific off Molokai, Hawai'i, during the "Ancient Sea Level Secrets" research cruise.

5 YEARS
OF SCIENCE ABOARD *FALKOR*

Founders Eric and Wendy Schmidt meet with past Principal Investigators and Chief Scientists at the Falkor Five Year Anniversary events in Honolulu, Hawai'i. The group discussed strategies for advancing ocean sciences with innovative technologies.

Co-founders Eric and Wendy Schmidt learn about expedition results and their impact with Dr. Jeff Drazen at the Five Years of Science aboard Falkor celebration at the Waikiki Aquarium.

5 YEARS
OF SCIENCE ABOARD *FALKOR*

In 2017, Schmidt Ocean Institute celebrated five years since *Falkor* was launched on her mission to transform marine science with innovative technologies and approaches, and the open sharing of knowledge.

Today, Schmidt Ocean Institute is known as the world's first fully privately-funded research vessel operator dedicated to advancing the frontiers of ocean science and conservation. Our work has helped to inspire and disrupt the status quo in ocean research by encouraging other independent thinkers to apply diverse, practical innovation to understanding and protecting our oceans.

By mandating open sharing of data for all supported projects and by providing end-to-end data acquisition, management, processing, and sharing services to all collaborating researchers, Schmidt Ocean Institute has broken academic glass walls and removed barriers to cooperation among the scientists, research labs, and institutions around the world. Our open data policy has changed the attitudes to data sharing by shifting academic values in favor of openness, collaboration, and equal opportunity.

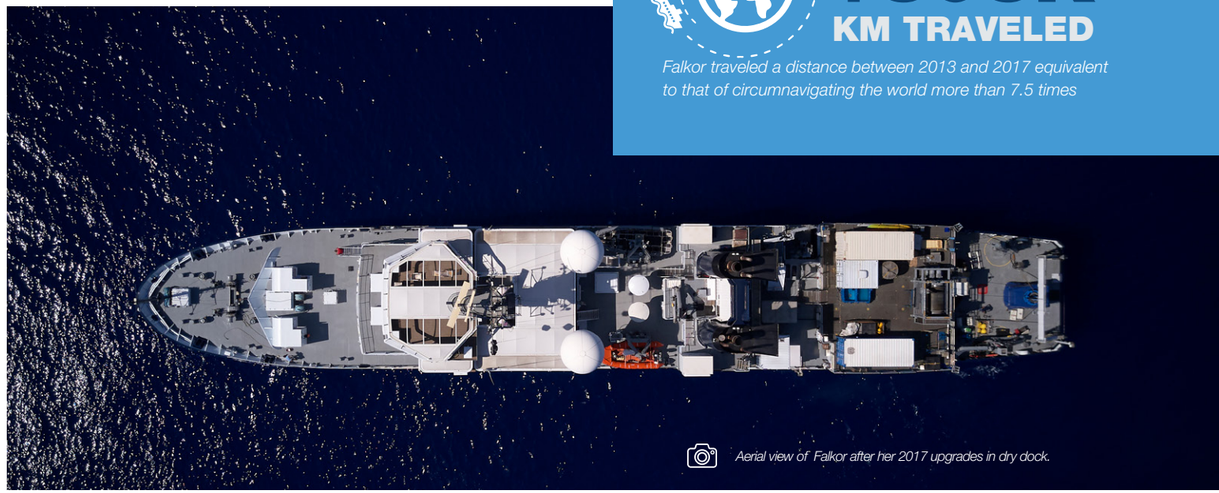
Open source software developed by Schmidt Ocean Institute for scientific data logging, in-cloud processing, and image annotation is being adopted by dozens of academic, government and philanthropic organizations around the world.

All Schmidt Ocean Institute programs are conceived and developed to create appreciation and understanding of ocean systems among people who are not marine scientists.

When you consider that most of the processes that determine the function of the biosphere and the fate of our civilization are linked with the ocean, you realize that we have life-saving messages to deliver. By characterizing intricate marine ecosystems and sensitive habitats, as we did, for example, by mapping a third of the vast Papahānaumokuākea Marine National Monument ahead of its expansion, we provide critical data needed to improve conservation policy, resource management, and global awareness, leading to stronger protection of our life-giving oceans.

+303K
KM TRAVELED

Falkor traveled a distance between 2013 and 2017 equivalent to that of circumnavigating the world more than 7.5 times



Aerial view of Falkor after her 2017 upgrades in dry dock.

By way of an unprecedented mass-extinction, the oceans are heading towards a new global equilibrium, which could as well be incompatible with humankind. The grand challenge of protecting the declining marine life, the global climate regulator, looms large. It is aggravated by the chasm between the ocean's enormous size and complexity and our limited capacity to characterize it at relevant scales in space and time. As never before, oceans depend on us for swift action to develop orders of magnitude more scalable, yet robust, environmental assessment techniques and sophisticated, yet easy to use, data analysis tools to enable intelligent, affordable, and effective marine ecosystem care and restoration around the globe.

To our advantage, exponential advancements in data technologies, mobile and cloud computing, deep learning, and low cost, intelligent, environmentally-friendly robotics offer a rich set of tools to devise effective ecosystem management practices, inform globally extensible conservation strategies, and raise public awareness and engagement.

In the end, it doesn't matter where you live or what you do. Everyone, everywhere should care about the oceans, our shared planetary life support system.

Kate Herries, Master's candidate at the University of Hawai'i at Mānoa, shows samples of ancient drowned corals at the Falkor and NOAA Okeanos Explorer Open House, part of Falkor's Fifth Year Anniversary events in October. The samples were gathered by ROV SuBastian during the "Ancient Sea Level Secrets" research cruise.

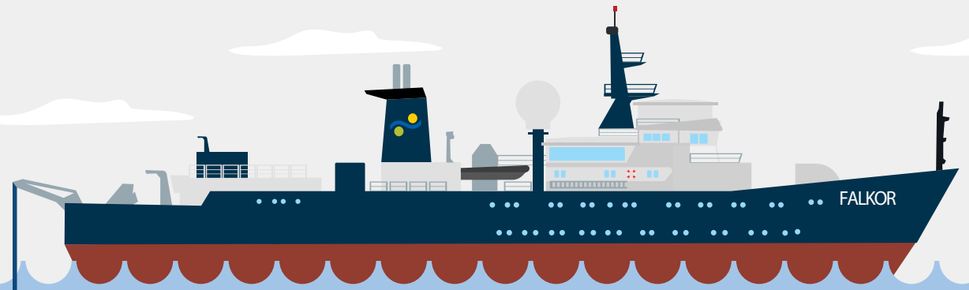
ROV SuBastian completed its first **100 dives,** *a significant milestone since field-testing in 2016*

ROV SuBastian places a marker down near a hydrothermal vent chimney at ~2,300 meters depth to celebrate the ROV's 100th dive during the "Underwater Fire" expedition in the Kingdom of Tonga.

ROV SuBastian is recovered onto the aft deck during the "Ancient Sea Level Secrets" research cruise.

The "Deep Corals of PIPA" science party in the wet laboratory aboard Falkor with all of the specimens collected during one of the deep-sea ROV dives. From left to right: Alexis Weinnig, Abigail Keller, Luke McCartin, Anna Gauthier, Tim Shank, Erik Cordes, Daniel Vogt, Aranteiti Tekiau, Randi Rotjan.

NUMBERS AND METRICS | *Falkor* 2013 - 2017



5 YEARS OF SCIENCE ON FALKOR

+303K KM TRAVELED

Falkor has traveled a distance greater than circling the globe 7.5 times

42 RESEARCH CRUISES

940 SCIENCE DAYS

160 INSTITUTIONS FROM 27 COUNTRIES

565 SCIENTISTS

216 STUDENTS

628 CTD CASTS

38 AUV DIVES

580,257 KM²
(an area the size of Kenya)
MAPPED BY *FALKOR*'S MULTIBEAM AND ECHO SOUNDER SYSTEM

14 DISCOVERED AND NAMED UNDERWATER FEATURES

2017 OUTREACH

LIVE GOOGLE HANGOUTS ON AIR
had 260,581 views from 174 countries

715 PEOPLE
on *Falkor* tours

3,130 STUDENTS
reached through 44 ship to shore connections

1048 ARTICLES
in the press in 2017

Data Sharing

320 TB OF DATA
collected on *Falkor*

197 GB OF DATA
of *Falkor's* data downloaded from MGDS in 2017

5,069 FALKOR DATA FILES
downloaded from MGDS in 2017

+211K 1-MINUTE REPORTS
of meteorological and thermosalinograph data sent to the Shipboard Automated Meteorological and Oceanographic System (SAMOS). This equates to over 5 million individual data values

159 DAYS OF DATA
sent to the Shipboard Automated Meteorological and Oceanographic System (SAMOS)

+72K KM² OF SHIP-TRACK COVERAGE
submitted to the Global Multi-Resolution Topography synthesis since 2012

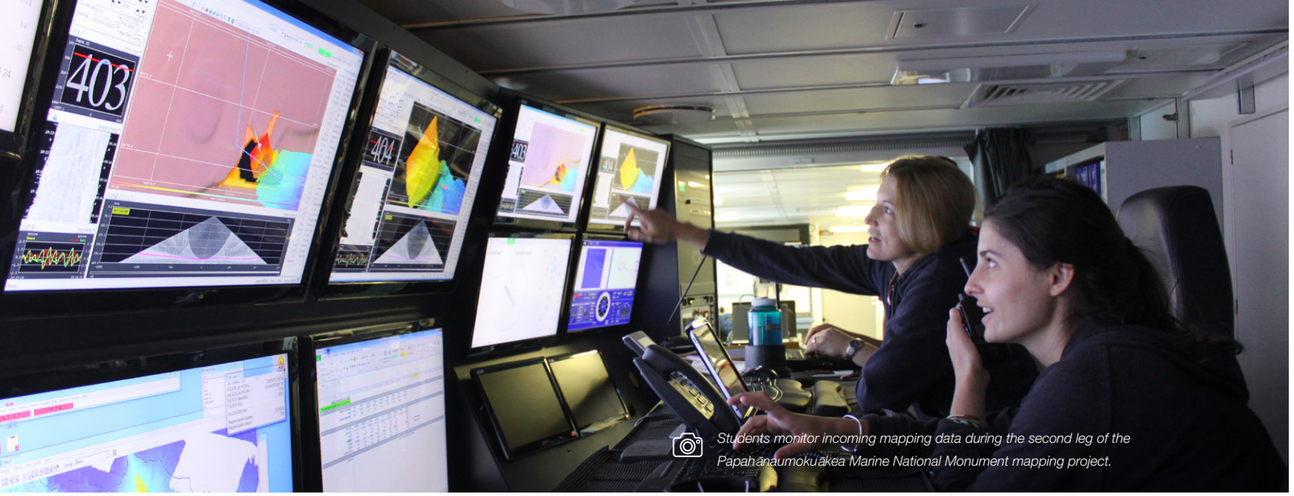
+360K KM² OF MAPPING DATA
submitted to the Global Multi-Resolution Topography synthesis since 2012

ROV SuBastian

105 SUCCESSFUL DIVES
56 dives in 2017

429 HOURS DIVE TIME
completing science

664 HOURS ON AIR
livestreaming in 2017



Students monitor incoming mapping data during the second leg of the Papahānaumokuākea Marine National Monument mapping project.

ADVANCING SCIENCE THROUGH INNOVATION ABOARD *FALKOR*

Tested and refined new soft robotics actuators for collection of fragile samples, aptly named "squishy fingers," that were fabricated aboard the ship using 3D printing.

Collected 200,000 images to complete a 3D reconstruction of a hydrothermal vent field to enable users to visualize the data using virtual reality technology.

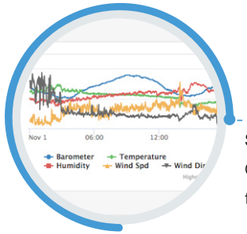
Supported the development of a web-based marine scientific image annotation software, Squidle+, by GreyBits that gathers image tags to train deep learning habitat characterization algorithms, and its shipboard version for annotation of ROV image data in real time.

A high endurance and high payload vertical take-off and landing robotic aerial vehicle was launched, recovered, and successfully operated for the first time from a research ship in the open ocean environment.

Designed, developed, tested, and put into full operation a 4,500 meter science work class dedicated remotely operated vehicle, SuBastian, equipped with 4K image collection capabilities, which allowed livestreaming of never-before-seen footage of deep coral and hydrothermal vent systems.

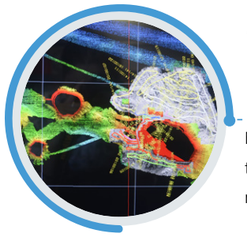
Collected the first measurements of sea surface skin salinity with an unmanned aerial vehicle, demonstrating that the surface microlayer of the ocean is saltier than originally thought.

Pioneered new ways to trace phytoplankton with cutting-edge instruments such as the NASA-funded Flowthrough Extended Range Particle Sizer (FERPS). The collected data is used to create remote sensing algorithms reducing uncertainties in biogeochemical models.



Supported the development of Open Vessel Data Management (OpenVDM) software by OceanDataRat, which organizes all oceanographic data gathered on research vessels and allows technicians and public to view data in real-time both on the ship and online.

Falkor was the first research vessel to have installed a high performance computing (HPC) system permitting shipboard scientists to model collected data in real-time and make informed decisions about where to conduct at-sea research.



Mapped 35% of the United States' Papahānaumokuākea Marine National Monument, as part of the efforts that lead to its historic expansion that quadrupled its size and made it the largest marine national monument of the United States.

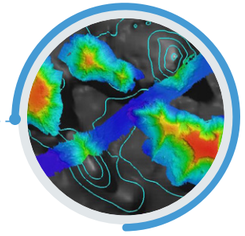
Researchers at sea visualized phytoplankton for the first time with virtual reality in 3D, allowing the science team aboard Falkor and collaborators on shore to interactively immerse themselves into the unique holographic data.

Researchers collected ancient coral specimens that lived 10,000-20,000 years ago. Radiometric dating of the coral skeletons will allow scientists to reconstruct the timing of sea level change and predict future rates of sea level rise.

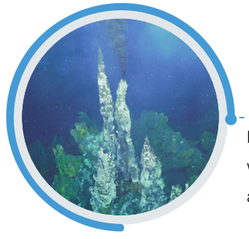
Completed the first comprehensive survey of the eastern seamounts in the UNESCO World Heritage Site Phoenix Islands Protected Area, conducting the largest inventory of species distributed by depth and discovering two new species.

Falkor off Greenland, as she makes her way from her 2012 conversion in Germany to begin 2013 research cruises around North America.

Supported the first use of proteomics using biomarkers and mass spectrometers for the diagnosis of oceanic changes instead of medical aspects to track long-term changes in microbial communities in expanding oxygen minimum zones. The resulting dataset is thought to be the largest, most complete protein dataset yet for the oceans.



Produced high resolution seafloor maps for more than 11,000 square kilometers of the United States' Johnston Atoll Unit which were used to strategically guide robotic submersibles on a follow up cruise aboard a ship US government research vessel to characterize the living and non-living resources.



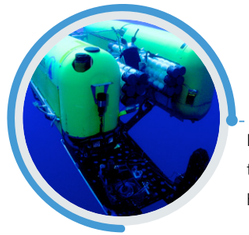
Discovered and mapped ten new underwater eruption deposits in the Tonga subduction zone within the waters of the Kingdom of Tonga, including three new hydrothermal chimney systems and several diffuse venting sites.

Demonstrated the feasibility of using ROVs as an accurate and low-impact fisheries assessment tool and helped to inform the management of artificial reefs in a way that allow the surrounding fish communities to thrive. *[Ajemian, M.J., et al. (2015). Rapid assessment of fish communities on oil and gas platform reefs using remotely operated vehicles. Fish. Res. 167: 143-155, doi:10.1016].*

Documented the response of deep-water corals to oil–dispersant mixtures following the Gulf of Mexico Deepwater Horizon oil spill, providing evidence of their toxicity and information that can be used in future spill intervention. *[DeLeo, D.M., et al. (2015). Response of Deep-water Corals to Oil and Chemical Dispersant Exposure. Deep Sea Research II. doi: 10.1016/j.dsr2.2015.02.028].*

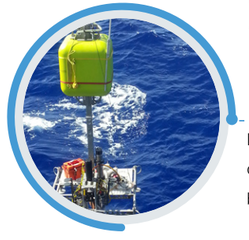
Demonstrated that Earth's sea level did not rise steadily during the last glacial melt giving evidence to quick sea level impacts *[Nauels, A., et al. 2017. Linking sea level rise and socioeconomic indicators under the Shared Socioeconomic Pathway. Environmental Research Letters 12 114002].* This suggests that past sea level rose by tens of millimeters annually, far beyond the current prediction, and may impact future sea level models. *[Khanna, Pankaj, et al. 2017. Coralgal reef morphology records punctuated sea-level rise during the last deglaciation. Nature Communications 1046 (8), doi:10.1038/s41467-017-00966-x].*

Produced the first seafloor maps of the Campeche Escarpment, looking at one of the largest meteor impacts in high resolution resulting in a better understanding of Earth's history *[Paull, C.K., et al. 2014. Cretaceous–Paleogene boundary exposed: Campeche Escarpment, Gulf of Mexico. Marine Geology 357, 392-400]* and identifying sediment failures in Mexican waters and potential tsunami impacts in the Gulf of Mexico. *[Chaytor, J.D., et al. (2016). Source Characterization and Tsunami Modeling of Submarine Landslides Along the Yucatán Shelf/Campeche Escarpment. Pure Appl. Geophys. 173: 4101, doi: 10.1007/s00024-016-1363-3].*

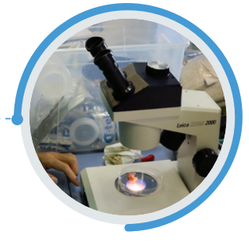


Discovered a new form of low-temperature seafloor fluid flow in the Mid-Cayman Rise within the Cayman Trough and extended the known range of physical conditions under which seafloor hydrothermal venting can exist.

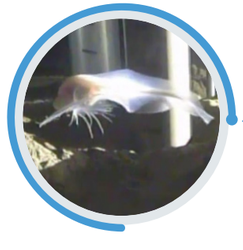
Studied microbes that live beneath the seafloor at Axial Seamount off the US West Coast, leading to an understanding of how these communities alter the flow of carbon and nutrients, and revealing high taxonomic diversity. *[Topçuoğlu B., et al. (2016). Hydrogen Limitation and Syntrophic Growth among Natural Assemblages of Thermophilic Methanogens at Deep-sea Hydrothermal Vents. Front. Microbiol. 7:1240. doi:10.3389/fmicb.2016.01240].*



Demonstrated that faunal communities in the Mariana Trench are zoned by depth and made up of heterogeneous environments. This has implications for conservation such that a trench cannot be thought of as a single habitat.



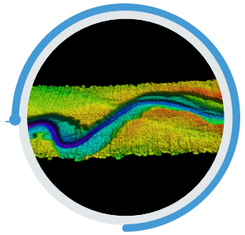
Discovered the presence of high pollutant concentrations in trench species showing that hadal environments are not immune to anthropogenic influences . *[Jamieson, A., et al. (2017). Bioaccumulation of Persistent Organic Pollutants in the Deepest Ocean Fauna. Nature Ecology & Evolution, 1:0051, doi:10.1038/s41559-016-0051]*



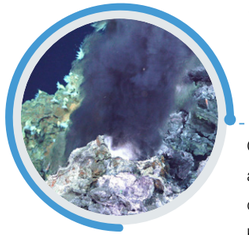
Identified a new hadal snailfish species, *Pseudoliparis swirei,* at a record depth with SOI's 11,000 meters capable elevator lander systems.

Hosted the first tests of pressure-retaining samplers and successfully collected microbes and amphipods at 10,900 meters. Results indicated that certain species have genetic adaptation to hadal environments. *[Lan, Y., et al. (2017). Molecular Adaptation in the World's Deepest-living Animal. Mol. Ecol. 26:14, DOI: 10.1111/mec.14149].*

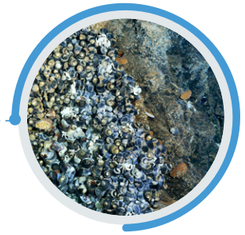
Demonstrated advanced autonomy in multi-platform robotic operations to support intelligent, scalable, and cost-efficient survey and characterization of marine environments, working towards reducing effort, time, and resources for ocean monitoring, exploration, and conservation.



Captured new faults along the Wharton Basin off the west coast of Indonesia, which may indicate that parts are subducting at different rates, causing strain in the plate boundaries *[Singh, S., et al. (2017). The Discovery of a Conjugate System of Faults in the Wharton Basin Intraplate Deformation Zone, Science Advances 2017 3: no. 1, doi: 10.1126/sciadv.1601689].* These findings updated tsunami hazard models, potentially protecting the lives of many that live along the coastal regions.



Completed the first comprehensive view of geologic, chemical, and biological diversity along the Mariana back-arc region, including the discovery of four new vent sites and the deepest historical eruption in the back-arc at 4,100-4,450 meters. This information will be used by managers of the United States' Mariana Trench Marine National Monument. *[Baker, E., et al. (2017). The Effect of Arc Proximity on Hydrothermal Activity Along Spreading Centers. Geochem. Geophys. Geosyst. doi:10.1002/2017GC007234].*



Collected biological and chemical data for contribution to a ten-year time series about hydrothermal vent sites in the Lau Basin. The vents were shown to have stable habitats, which contrasts previous assumptions that vents are unstable and can recover quickly from perturbations such as deep sea mining. *[Du Preez, C. and C. Fisher. (2018). Long-Term Stability of Back-Arc Basin Hydrothermal Vents. Frontiers of Marine Science, 5:54, doi: 10.3389/fmars.2018.00054].*

Deck crew and ROV team guides SuBastian safely back to the ship after the first science dive at Daikoku during the "Searching for Life in the Mariana Back-Arc" expedition.

The research team and ship's crew after crossing the North Pacific Ocean -from Hawai'i to Portland- during the "Sea to Space Particle Investigation" expedition.

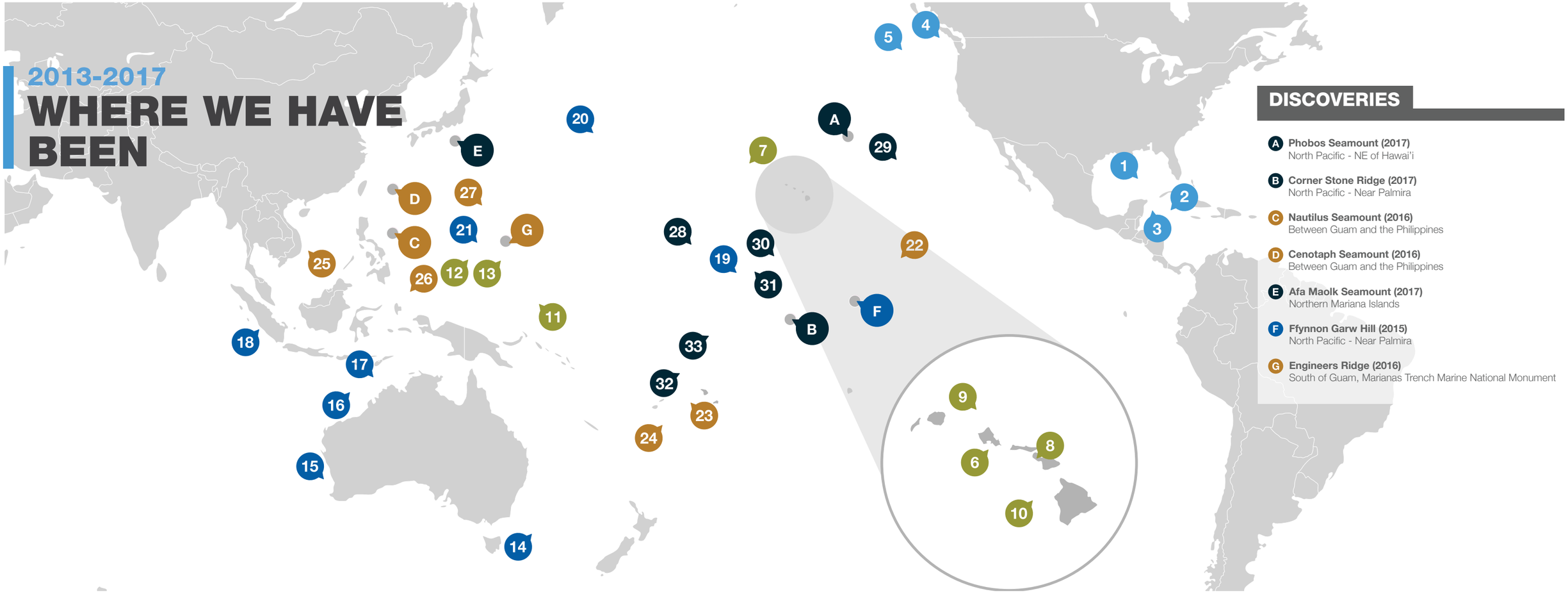
Benjamin Knorlein - a Computer Scientist with the Center for Computation and Visualization at Brown University - is developing software to visualize holographic images of marine plankton using interactive 3D virtual reality on the “Sea to Space” expedition.

A night deployment of AUV REMUS 600 on the aft deck of Falkor during the "Unraveling Ancient Sea Level Secrets" research cruise involved the work boat. The Autonomous Underwater Vehicle was set off overnight to gather high resolution mapping over Penguin Bank off Molokai.

Falkor in the blue waters of the Pacific during the "Ancient Sea Level Secrets" research cruise.

2013-2017

WHERE WE HAVE BEEN



DISCOVERIES

- **A Phobos Seamount (2017)** North Pacific - NE of Hawai'i
- **B Corner Stone Ridge (2017)** North Pacific - Near Palmira
- **C Nautilus Seamount (2016)** Between Guam and the Philippines
- **D Cenotaph Seamount (2016)** Between Guam and the Philippines
- **E Afa Maolk Seamount (2017)** Northern Mariana Islands
- **F Ffynnon Garw Hill (2015)** North Pacific - Near Palmira
- **G Engineers Ridge (2016)** South of Guam, Marianas Trench Marine National Monument

2013

1. Imaging the K-T Boundary
Fort Lauderdale, USA - St. Petersburg, USA
Mar 9 - 29

2. Hydrothermal Exploration
St. Petersburg, USA - Montego Bay, Jamaica
May 30 - Jun 30

3. Serendipitous Side Trip
Roatan, Honduras
July 8 – 13

4. Open Ocean to Inner Sea
Nanaimo, Canada - Victoria, Canada
Aug 18 - Sep 16

5. Axial Seamount Cruise
Victoria, Canada
Sep 22 - Oct 4

2014

6. The Secret Lives of Whales
Honolulu, USA
Feb 16 - 22

7. Papahānaumokuākea Monument
Honolulu, USA
Mar 7 - Apr 11 & May 2 - Jun 6

8. Deeper Views
Honolulu, USA
Apr 18 - 24

9. Net Gains at Station ALOHA
Honolulu, USA
Jun 13 - 19

10. The Iron Eaters of Loihi Seamount
Honolulu, USA
Jun 25 - Jul 7

11. The Mysteries of Ontong Java
Pohnpei, Federated States of Micronesia - Haganta, Guam
Oct 15 - Nov 2

12. Exploring the Mariana Trench
Haganta, Guam
Nov 9 - Dec 9

13. Expanding Mariana Trench Perspectives
Haganta, Guam
Dec 15 - 21

2015

14. Tracking the Tasman Sea's Hidden Tides
Hobart, Australia
Jan 17 - Feb 13

15. Perth Canyon: First Deep Exploration
Henderson, Australia
Mar 1 - 12

16. Coordinated Robotics
Broome, Australia
Mar 24 - Apr 6

17. Timor Sea Reef Connections
Broome, Australia - Darwin, Australia
Apr 10 - May 4

18. Unlocking Tsunami Secrets
Singapore - Padang, Indonesia - Singapore
May 23 - Jun 29

19. Mixing Up the Tropical Pacific
Singapore - Honolulu, USA
Jul 28 - Aug 19

2016

20. Magnetic Anomalies of the World's Largest Volcano
Honolulu, USA - Haganta, Guam
Oct 5 - Nov 10

21. Hydrothermal Hunt at Mariana
Haganta, Guam
Nov 18 - Dec 15

22. Investigating Life Without Oxygen in the Tropical Pacific
Honolulu, USA
Jan 16 - Feb 11

23. Virtual Vents: The Changing Face of Hydrothermalism Revealed
Suva, Fiji
Mar 20 - Apr 1

24. Ecosystem Dynamics of Hydrothermal Vent Communities
Nukualofa, Tonga
Apr 7 - May 5

25. A Changing River: Measuring Nutrient Fluxes to the South China Sea
Nha Trang, Vietnam
Jun 3- 19

2017

26. Study of the Sea-Surface Microlayer and Air-Sea Boundary
Darwin, Australia - Haganta, Guam
Oct 10 - Nov 9

27. Searching for Life in the Mariana Back-Arc
Haganta, Guam
Nov 29 - Dec 20

28. Eyes Below the Surface: Mapping Johnston Atoll
Haganta, Guam - Honolulu, USA
Dec 29 - Jan 16

29. Sea to Space: Particle Investigation
Honolulu, USA - Portland, USA
Jan 24 - Feb 20

30. Unraveling Ancient Sea Level Secrets
Honolulu, USA
Aug 25 - Sep 5 & Sep 11 - 27

31. Discovering Deep Sea Corals of the Phoenix Islands
Honolulu, USA - Kanton, The Republic of Kiribati - Apia, Samoa
Oct 5 - Nov 1

32. Underwater Fire: Studying the Submarine Volcanoes of Tonga
Apia, Samoa
Nov 10 - Dec 17

33. Filling The Gaps: Mapping Ellice Basin
Apia, Samoa - Honolulu, USA
Dec 24 - Jan 9, 2018

Ariell Friedman is the founder and principal data scientist at Greybits Engineering, a data science and software engineering consultancy that is developing Squidle+, an innovative video annotation software being used aboard Falkor.

DATA
STEWARDSHIP & ENGINEERING

The volumes, complexity, and diversity of oceanographic data grow rapidly. This highlights a new challenge, a large disparity between the accelerating growth of observational data and the lack of scalability of legacy analytical and interpretational workflows. At the same time, accelerating innovation in data technologies, cloud computing, and deep learning offers exciting opportunities to revolutionize legacy routines. This section reviews our ongoing efforts and new initiatives to advance data stewardship, sharing, interpretation, visualization, and analysis while providing the general public with reliable access to oceanographic data.

159

days of data sent to the Shipboard Automated Meteorological and Oceanographic System (SAMOS)

+360K

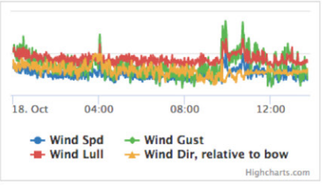
Km² of mapping data submitted to the Global Multi-Resolution Topography synthesis since 2012

PARTNERSHIPS

Rolling Deck to Repository (R2R) curates data collected by sensors embedded on research vessels, such as navigation, fluorometer, raw multibeam, thermosalinograph, conductivity, temperature, depth, and Acoustic Doppler Current Profiler (ADCP) data. By submitting data to R2R, SOI leverages a wide oceanographic data network. R2R links users to the meteorological and current velocity data that is sent to the Shipboard Automated Meteorological and Oceanography System (SAMOS) and the University of Hawai'i Data Acquisition System (UHDAS), and contributes to NOAA's National Center for Environmental Information and DataOne.

Processed bathymetric, side scan sonar, and echosounder data, vehicle-collected data such as navigation, conductivity, temperature, and depth (CTD), oxygen, magnetometer and other robot-carried instruments are curated by Marine Geoscience Data System (MGDS).

Our partnership with MGDS ensures that seafloor bathymetric data reaches more users and contributes to a variety of syntheses such as the Global Multi-Resolution Topography synthesis, Google Earth Basemap, and ESRI Basemap.



CLOUD SERVICES

This year, in collaboration with R2R, SOI tested the multibeam data quality assurance workflow in Google Cloud Platform (GCP) Compute Engine. "Google's support for customizable virtual machines allowed R2R to port the MBQA code and supporting libraries without fundamentally changing the I/O and existing workflow," said Dr. Suzanne Carbotte, Principal Investigator for R2R, about running the test. "Additionally, R2R realized a performance gain of 35% in runtimes with cloud environments and noted a clear advantage is that the CPU and IO intensive process can be run without competing for compute resources with other R2R tasks."

SOI continues to support the development of the Open Vessel Data Management (OpenVDM) software and web service. It enables flexible viewing and management of ship's sensor data in real-time and delayed modes. SOI's support for the development of this "open-infrastructure" data management software led to its broad adoption by many research vessels, including R/V Helmer Hanssen, R/V Atlantic Explorer, R/V Endeavor and R/V Annie. Expansion of OpenVDM in 2018 will enable the management of data from deployable platforms such as AUVs and ROVs, including ROV SuBastian and ROV Yogi.

Fisheries and Oceans Canada employees and collaborators participated in an image annotation workshop focusing on Squidle+.

VIDEO ANNOTATION

Since 2016, Schmidt Ocean Institute has been supporting the development of Squidle+ (squidle.com.au), an open source scientific image annotation software and web service.

Squidle+ supports intuitive access, browsing, management, annotation, sharing, and interpretation of georeferenced marine imagery. The program is available continuously as a web service online, where it provides access to about 5 million oceanographic images.

A version of Squidle+ for shipboard image annotation and event logging was developed in 2017 to allow the scientists aboard *Falkor* to annotate images collected with ROV SuBastian.

This application provided a collaborative environment where scientists can log ROV events and annotate the contents of scientific images using a naming convention of their choice.

As Squidle+ continues to be further developed, local annotations will be automatically synchronized with the cloud to allow scientists to access and continue their image and video analysis at any time from anywhere in the world. In a related effort, SOI has supported the development of Ocean Video Lab (OVL, www.oceanvideolab.org), which provides a lightweight annotation interface for YouTube hosted marine videos. It coordinates the video stream with the platform's geospatial data, and provides an easy to use annotation search tool to facilitate video analysis.

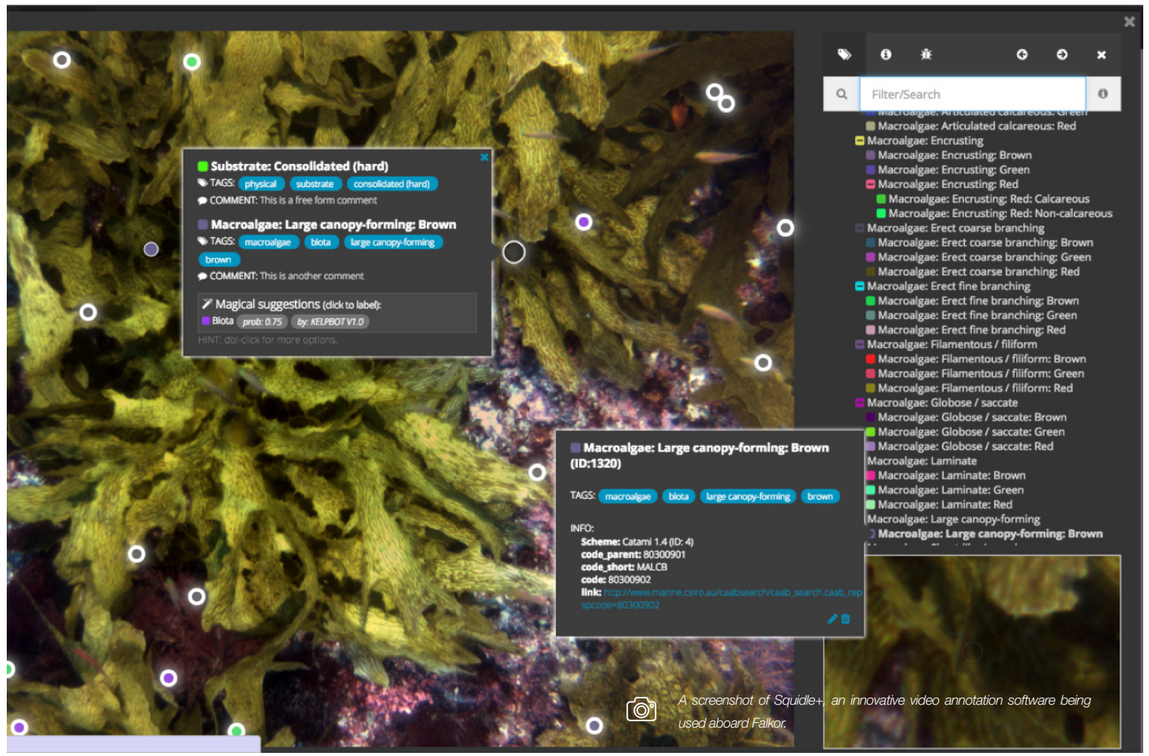
In 2017, OVL is a responsive web application with features that can be called via Application Programming Interfaces (APIs). It provides links to data resources, supports annotation filtering, and allows the users to download geolocated observations in a variety of formats. OVL is now employed by NOAA's Office of Ocean Exploration and Research to engage citizen scientists.

DATA VISUALIZATION

Our first research expedition of 2017 hosted a computer scientist and visualization expert providing unique opportunities for data processing and holographic visualization. Ben Knorlein, from Brown University, was aboard *Falkor* to help scientists use Virtual Reality (VR) to see plankton in 3D space. The resulting immersive visualizations helped the scientists interpret how the phytoplankton are congregating in relation to each other.

The high-performance computing (HPC) system aboard *Falkor* helped the team establish a pipeline for processing the holographic images so that they could test different settings, run data analysis in parallel, and test which settings resulted in the best data.

The HPC system was also used to host Squidle+, train its new scientific users sailing aboard *Falkor*, and run MapTracker, an open source software developed to visualize the locations and track multiple simultaneously operating robotic platforms, monitor their status and performance, and interactively control and deconflict their activities. Advancements in data engineering and software hold promise for dramatic future improvements in oceanographic research, ecosystem management, and conservation in a scalable, efficient, and transferable manner. While maintaining its focus on the advancements of software and data technologies, SOI remains committed to maintaining state of the art cybersecurity for its infrastructure and collaborators, and keeping its research program outcomes open to the public.



A screenshot of Squidle+, an innovative video annotation software being used aboard Falkor.

IT STARTS WITH
COMMUNITIES

Co-founder Wendy Schmidt and Director of Operations Eric King review the guestbook in Falkor's Library.

"Our vision is to talk about ocean research in ways that reach people where they live - whether they are a student, researcher, scientist, artist, or farmer. It doesn't matter what you do or where you are, this is your life support system."
- Wendy Schmidt

Outreach to the communities that we work in is a priority for Schmidt Ocean Institute, and the reason is quite simple, open sharing of information matters very little if no one knows or cares about it. Our commitment to bringing ocean science to the public is supported by an array of programs, training, broadcasts, and social media campaigns that encourage and facilitate engagement between participating researchers and the public.

Expedition Outreach

In 2017, scientists, artists, and scholars aboard *Falkor* connected with over 3,000 students in locations such as Hawai'i, Guam, Dominican Republic, Scotland, and Australia through our live Ship-to-Shore video call program. This year, new collaborations with Exploring By The Seat Of Your Pants, United States National Aeronautics and Space Administration (NASA) Globe Educators, and Sustainable Coastlines Hawai'i provided an opportunity for us to reach more classrooms and communities than ever before.

We also continued our World Ocean Day tradition hosting a tri-ship Hangout online with NOAA's Okeanos Explorer and Ocean Exploration Trust's E/V Nautilus. This year our expeditions were also featured in an online program through Oregon Coast Aquarium's Oceanscape Network, reaching over 24,000 people, making it the most viewed virtual expedition on Oceanscape to date.

Schmidt Ocean Institute works with a team of very talented multimedia correspondents who connect scientists and crew to the rest of the world through regular blogs, social media content, and weekly videos. Over 400,000 pages have been viewed on the SchmidtOcean.org website this past year, from nearly every country in the world. It has been an honor to feature blogs written by student participants, scientists, and artists, and Schmidt Ocean Institute will continue hosting science communication training sessions for science teams, encouraging and facilitating this kind of public engagement.

Showcasing the cutting-edge research undertaken aboard *Falkor* led to over 940 news stories in 2017, including national and international television, radio, print, and web publications. Some highlights include SOI research featured in articles from National Geographic, Wired, Scientific American, NASA TV, and Nature.

This research was shared with technical and public audiences, as well as through presentations, booths, and training reaching more than 260,000 people. Notable examples of this included a panel on how technology can save the oceans at the International Ocean Film Festival, a seminar for staff at the Jet Propulsion Laboratory, and hosting a lecture series at both Hanauma Bay Education Center and Waikiki Aquarium.

A classroom connects to Falkor during the "Deep Corals of PIPA" expedition, where students viewed locations concurrently with researchers exploring the area.

Marine Technician Paul Duncan showcases the science control room during ship tours in Honolulu.

The Mariposa Foundation in the Dominican Republic connects with Falkor, meeting some of the women on the "Eyes Below" expedition.

Livestream Video

2017 was a record-breaking year for our live video presence. ROV SuBastian made 47 dives, resulting in over 465 hours (19 days) worth of footage, all of which was streamed live to YouTube and maintained as a publicly accessible archive. This year alone, more than 260,000 people tuned in to livestreams, blogs, and our new 4K video highlights on YouTube, nearly three times more than in 2016.

This year we also began streaming ROV SuBastian dives to Facebook Live, attracting more than 3 million viewers and pick-ups by external groups such as IFLScience.

The live, breathtaking footage from some of the most remote places in the world was selected and used for educational video initiatives, such as the BBC's Oceans, The Weather Channel, Discovery Channel Canada, and NHK documentaries. ROV footage was even showcased at the Berlin Atonal Festival and the International Ocean Film Tour. These livestream events are an invaluable way to involve large numbers of people from all walks of life in ocean research.

1,610,495 MINUTES
of livestream watched on YouTube in 2017

Educators work together at SOI's first teacher workshop led by Jena Kline who sailed aboard Falkor during the "Eyes Below: Mapping Johnston Atoll" expedition. She coached the group on how to use data and information gathered during SOI research cruises into school lesson plans.

Student Training

Schmidt Ocean Institute offers berths of opportunity to undergraduate and graduate students who require at-sea research experience. Encouraging these students to work with and learn from experts, has shaped their career outlooks and continues to be a valuable experience. *Falkor* has hosted 125 students from 55 universities in 16 countries since the start of operations in 2012, including 13 students brought aboard through the Student Opportunities Program and several on-shore Science Communications Internships. Student Opportunities participants reported increased confidence and interest in ship-board research, equipment, methods, and data.

Exposure to blog writing and ship-to-shore calls while on board also greatly increased students' comfort and interest in science communication and writing.

Our *Falkor*-inspired lesson plans created by Jena Kline, a teacher who sailed aboard *Falkor*, feature real multibeam and ROV video data to provide further enrichment for classrooms engaging with the scientists on board. These lessons were shared at a teacher workshop that we hosted at the Waikiki Aquarium to further support and engage educators connecting to the ship.

Pre- and post-cruise likert scale survey responses about increased comfort level with research, equipment, data, and mapping, and science writing and communication from 1 -Strongly Disagree to 5 - Strongly Agree, displayed as proportions of 100% (bar indicates 50%).

Celebrating Five Years of Research aboard *Falkor*

While docked in Honolulu, Schmidt Ocean Institute staff and crew celebrated five years of research aboard *Falkor*. An open house event welcomed over 700 members of the community to tour the vessel, our largest number of visitors to date. This was followed by a public event at the Waikiki Aquarium featuring interactive exhibits of research completed by science teams who have sailed on the ship. The celebration continued into the evening with a VIP event featuring speakers and a review video encouraging renewed connections and continuing inspiration. The participating scientists also came together for a round table discussion on the future of ocean science with co-founders Eric and Wendy Schmidt.

ROV SuBastian pilots hold position and operate the hydraulic arms to gather drowned reef samples during the second leg of the “Ancient Sea Level Secrets” research cruise.

"Lucy Bellwood drawing on deck during the "Eyes Below - Mapping Johnston Atoll".

ARTISTS
AT SEA

Visitors admire work at SOI's Artist-At-Sea exhibition at Sail Newport, presented with 11th Hour Racing.

SOI's Artist-at-Sea program flourished in 2017 adding several artists to the list of those who have sailed aboard *Falkor* since the program's inception. 2017 gave rise to the launch of a unique traveling exhibit featuring the works of the artists who have spent time at sea aboard *Falkor*. The artists' participation on science expeditions resulted in pieces that illuminate the research taking place, engaging conversation and imagination among scientists, artists, and the greater community.

"Getting kids and adults engaged in the science that is happening every day around the world is no small task. There are layers and layers of technical jargon to sift through, plus the necessity of contextualizing raw data in the grander scheme...The picture is too big to comprehend alone: we have to cooperate." - Lucy Bellwood

Lucy Bellwood presents to students after her voyage aboard Falkor. She produced a comic book about seafloor mapping which has been very well received by classrooms and educators.

The Artist-at-Sea exhibit now features over 50 pieces inspired by science and research carried out aboard *Falkor*, with work from over a dozen different artists. The new traveling exhibit was showcased at special venues including America's Cup in Bermuda, and in the United States at the International Ocean Film Festival in San Francisco, the Bishop Museum and the Arts at Marks Garage in Honolulu, Monterey Bay Aquarium Research Institute in Monterey, the NOAA Ocean Exploration Forum in San Diego, and the newly-built Sail Newport facility in Rhode Island. Several gallery opening events were held with remarks from the artists and Schmidt Ocean Institute co-founder Wendy Schmidt. Over 4,000 people attended these events, engaging in inspiring conversations about both the works themselves, as well as the science and technology they represent. The exhibit will conclude in the U.S. with a showing at the 2018 Ocean Sciences meeting in Portland, Oregon and a two-month display at the Aquarium of the Pacific in Long Beach, California.

Lucy Bellwood, a professional adventure cartoonist, was immersed in the world of seafloor mapping. Lucy crafted a *Falkor*-based comic book providing a layman's explanation of how multibeam mapping works and what the team discovered while mapping the Johnston Atoll. The resulting graphic story has become a powerful tool for public outreach, with more than 1,000 copies printed and distributed to students.

Kirsten Carlson worked alongside scientists as they used cutting-edge tools focused on understanding and measuring the color of the ocean. Kirsten found a natural, artistic complement to the advanced HyperSAS Radiometer by creating her own cyanometer. She also examined photos of surface water plankton from the state-of-the-art Imaging Flow Cytobot technology. “The diversity of shapes and sizes in phytoplankton is overwhelming... Seeing them first hand made me realize how interrelated all things are.” The captivating beauty she describes is presented in detail on the phytoplankton poster she created with ink and watercolor paints while aboard *Falkor*.

Kirsten Carlson drawing during “Sea To Space“ cruise.

“I hope that my passion for understanding nature through the lens of both science and art will give our audience the chance to connect with ocean science and new technology in new and imaginative ways. Art is an important tool that helps us see how interconnected the health of humanity is to the oceans and life on this planet.” - Kirsten Carlson

Natasha Russell drawing at “Sea Level Secrets“ cruise.

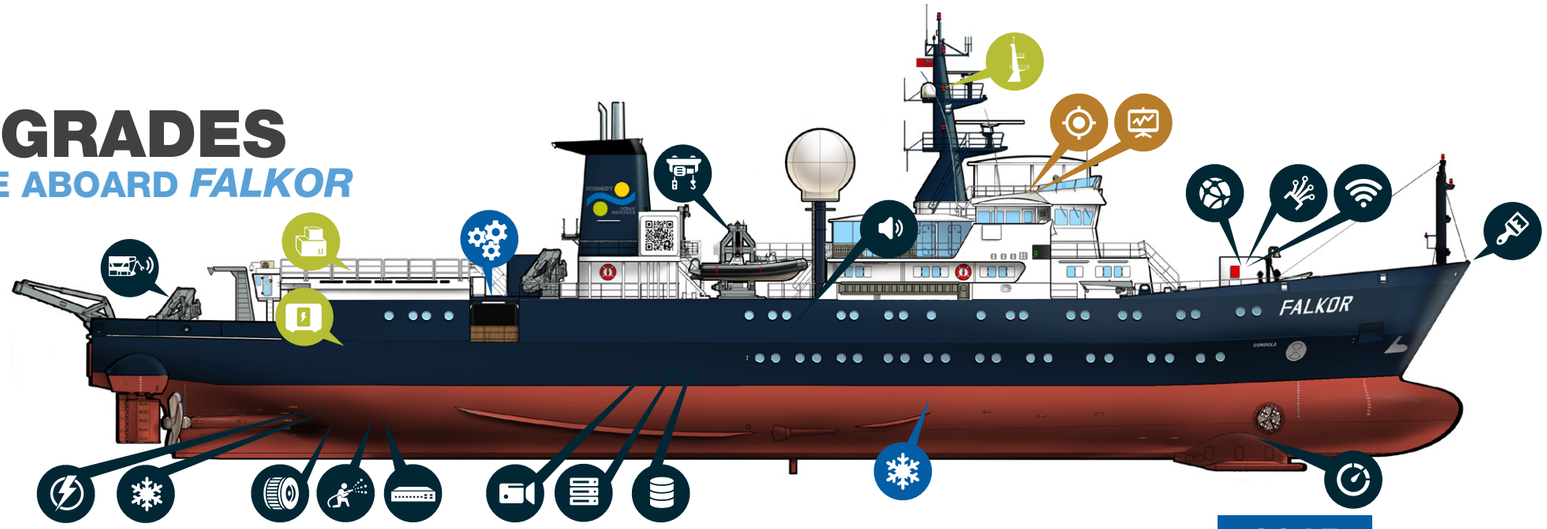
*“I hope my artwork will be received in a way that enables a wider understanding of this research for persons without a specific background knowledge of oceanography. At the same time, I would like to make something that provides a fresh perspective to those involved in the research.”
- Natasha Russell*

Artist and illustrator Natasha Russell joined the “Sea Level Secrets” expedition and immersed herself in a range of activities gaining inspiration from ancient drowned reefs. She combined the use of computer-generated imagery, images of physical samples, the surrounding environment, and data interpretations to create abstract, yet representative drawings that can be combined together into large-scale screen prints. The work reflects the way that different types of research results are layered together and interpreted as one larger picture. “The intention was to make artwork that can reveal the scientific process used in this research.” This includes helping audiences to get a sense how the process moves from a wide, overall macroscopic view to a very detailed and precise scale, as well as introducing the massive processing of data that is needed to shift the understanding from not simply “What is there?” but the more complex “Why is it happening?”

Rebecca Rutstein talks with attendees at the Artist-at-Sea exhibition at Sail Newport, presented with 11th Hour Racing.

FALKOR UPGRADES

5 YEARS OF SCIENCE ABOARD *FALKOR*



2013

OUR JOURNEY ABOARD *FALKOR* BEGINS

2014

SCIENCE STORAGE DECK
Above Wet Lab and Staging Bay

Removed the helideck and replaced with a custom new deck with fittings for 10 foot and 20 foot sized international standard shipping containers. Added connections for power, water, and compressed air to support science laboratory and control vans. Deck also has a special foundation to support the ROV winch system.

REPLACED EMERGENCY GENERATOR
Main Deck

Replaced existing generator with a new, higher-capacity generator.

MODIFIED MAIN MAST
Main Deck

Installed more yardarms and platforms on upper mast for additional science sensors and better access for maintenance.

2015

REPLACED #1 SEAWATER COOLING PUMP
Engine Room

Upgraded to a higher capacity pump.

INSTALLED NEW CTD LAUNCH & RECOVERY SYSTEM
Starboard Launching Bay

Installed new custom-built crane with docking head for launch, recovery and towing of science gear and equipment from the starboard side of the ship.

2016

UPGRADED INTEGRATED BRIDGE SYSTEM (ELECTRONIC CHARTS)
Bridge

A new version of the Electronic Chart System that involved software and hardware upgrades was installed.

UPGRADED THE DYNAMIC POSITIONING SYSTEM
Bridge

To increase efficiency during station-keeping and to reduce wear on the main engines, the dynamic positioning system received an extensive software upgrade.

UPGRADED STARBOARD WORKBOAT DAVIT
Boat Deck

Replaced the Davit's active heave compensated winch with a new system for improved at sea launch and recovery.

ADDED SECOND SPEED LOG
Gondola

A second speed log that works with a different technology (magnetic versus acoustic) was installed to increase sensor redundancy.

WIRELESS NETWORK
Falkor

All access points have been upgraded to support the latest wireless technology and increase bandwidth over WiFi.

SHIP'S NETWORK
Falkor

Switches replaced by chassis switches connected over 10Gbps fibre optics, with a redundant power supply.

2017

NEW COLORS
Falkor

The entire ship was repainted from mast to keel to reflect the new *Falkor* branding and better reflect modern ship color schemes.

ATSC MODULATION
Science Control Room and AV Room

Installation of Internal Video Modulation System over ATSC (Advanced Television Systems Committee). The system is capable of modulating video signal from the Digital Matrix into TV channels around the vessel.

NEW MAIN ENGINE OIL FILTERS
Engine Room

Installed automatic oil filters for main engines to improve lube oil filtration on engines.

NEW WATER MIST FIRE FIGHTING SYSTEM
Engine Room

Installed new automatic sprinkler system in the Engine Room and Emergency Generator Room.

HA SERVER
AV Room

Falkor's primary server was updated to HA (High Availability) architecture.

NETAPP SCIENCE STORAGE
AV Room

Additional 50TB was added to the NetApp Array.

INTERCOM ROV COMMUNICATIONS
Science Control Room, Library and Aft Deck

Installation of a state-of-the-art communication system for ROV operations available for the ROV Pilot Technicians and Science Team.

SHIP'S NETWORK
Falkor

Upgrades of cybersecurity inside the ship, including access control list for the network, training of the crew, implementation of password management system, ethical hacking and penetration testing conducted, monitoring software for network control, backup and recovery for configuration files, and monitoring of configuration changes.

UPGRADE MAIN SWITCHBOARD
Engine Control Room

Main switchboard upgraded to support the power from the new generators.

LIBRARY AUDIO UPGRADE
Library

Audio capabilities from ROV and science operations brought into the library.

REPLACED MAIN GENERATORS
Engine Room

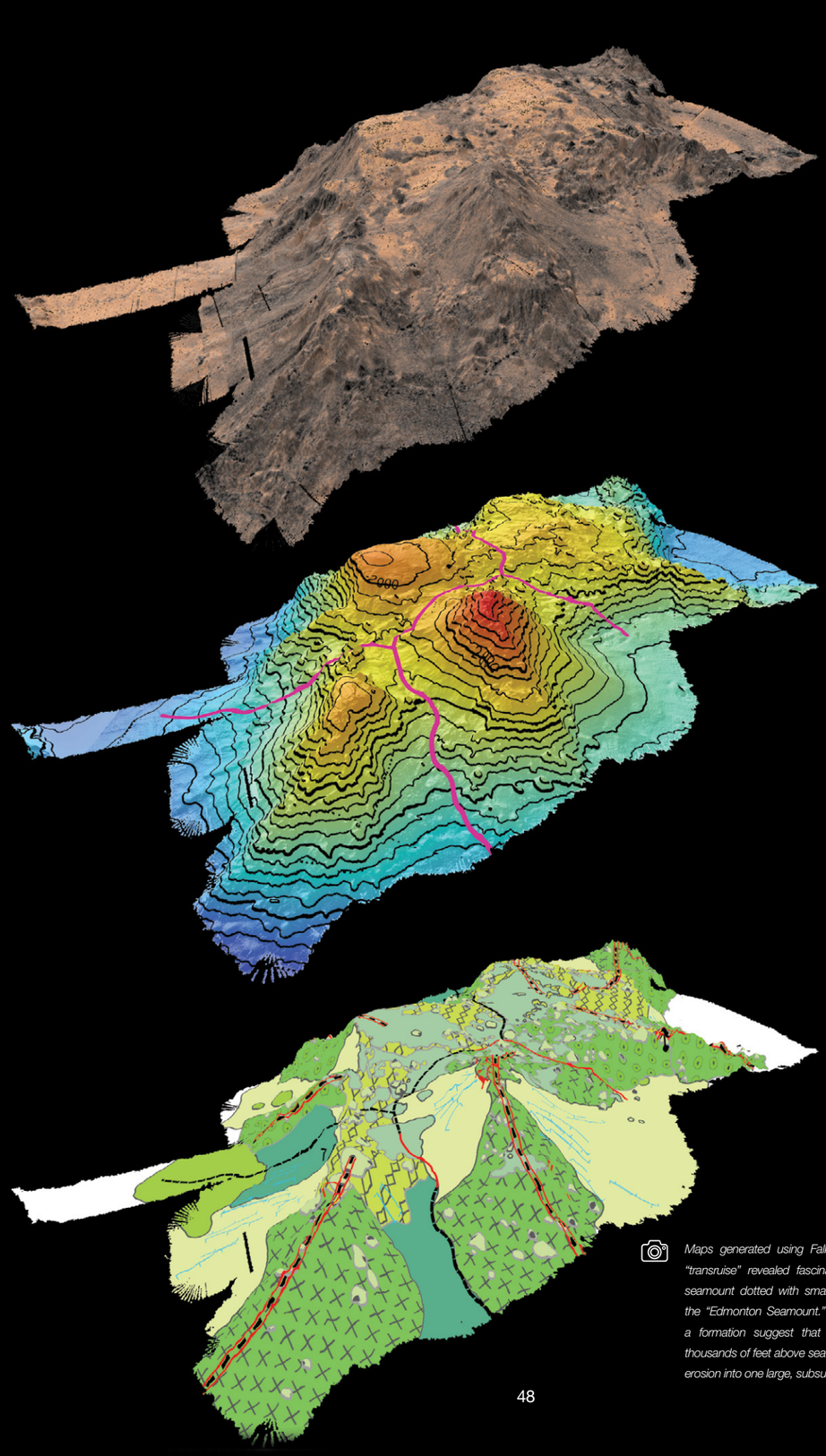
Installed two new MTU 16V2000 generators to replace original MWM generators and shaft generators. Increased electrical capacity from 500 KW to 720 KW for each generator.

AUTOMATED CONTROL SYSTEM FOR COOLING WATER PUMPS
Engine Room

Installed variable frequency drive system to control seawater cooling pumps to optimize their electrical power consumption.

Falkor's crew and contracted support team during 2017 drydock. The shipyard period included many upgrades, including the main generator replacements, major improvements to the ship's computer networks, and a complete repainting of the entire ship in a new color scheme.

Hydrothermal vent chimney close-up, showing crabs and snails. Despite the crushing pressure, extreme variations in temperature and complete lack of sunlight, life still thrives at vents such as this in the deep sea.



Maps generated using Falkor's multibeam sonar during this "transruise" revealed fascinating structures, including a large seamount dotted with smaller peaks, currently referred to as the "Edmonton Seamount." The geologic implications of such a formation suggest that four distinct volcanoes, reaching thousands of feet above sea level, merged through eruption and erosion into one large, subsurface mountain.

EYES BELOW
MAPPING JOHNSTON ATOLL

Cruise FK161229 | Dec 29th, 2016 - Jan 16th, 2017

CHIEF SCIENTIST
Dr. John R. Smith

PORT LOCATION
Guam - Honolulu

DOI:
10.7284/907182

LOCATION
Pacific Ocean

COLLABORATING ORGANIZATIONS:
University of Hawai'i at Mānoa, 11th Hour Racing

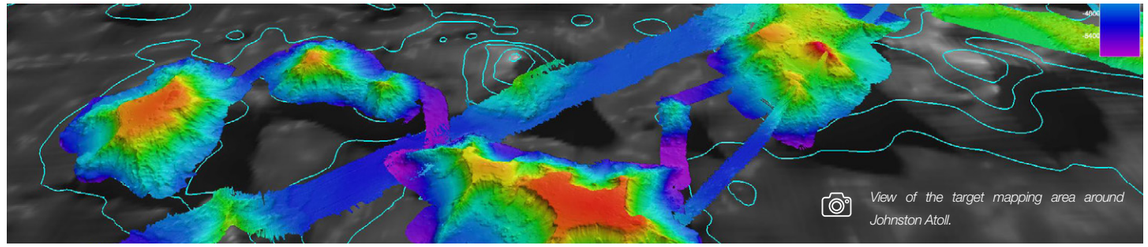
UNSURVEYED AREAS IN THE RECENTLY EXPANDED JAU WERE MAPPED TO IDENTIFY THE FEATURES WITHIN ITS BOUNDARIES, AND DOCUMENT HIGH-DENSITY BIOLOGICAL COMMUNITIES AND PHYSICAL RESOURCES SUCH AS POLYMETALLIC CRUSTS AND NODULES.

After transiting to one of the most remote parts of the world, *Falkor* began sending out sonar pings, creating detailed bathymetry maps of the Johnston Atoll Unit (JAU). Located in the Pacific Remote Islands Marine National Monument approximately 700 nautical miles southwest of the Hawaiian Islands, the JAU is of both biological and geological interest to researchers. Over 11,000 square kilometers of the ocean floor were mapped in high-resolution during this expedition.

During *Falkor*'s repositioning from the island of Guam to Honolulu, a research team led by Principal Investigator John R. Smith from the University of Hawai'i, visited the recently expanded boundaries of the U.S. marine protected area, allowing them to map a region nearly the size of the U.S. state of Connecticut. Unsurveyed areas in the JAU were mapped to identify the features within its boundaries, and document sites that may harbor high-density biological communities and resources such as polymetallic crusts and nodules.

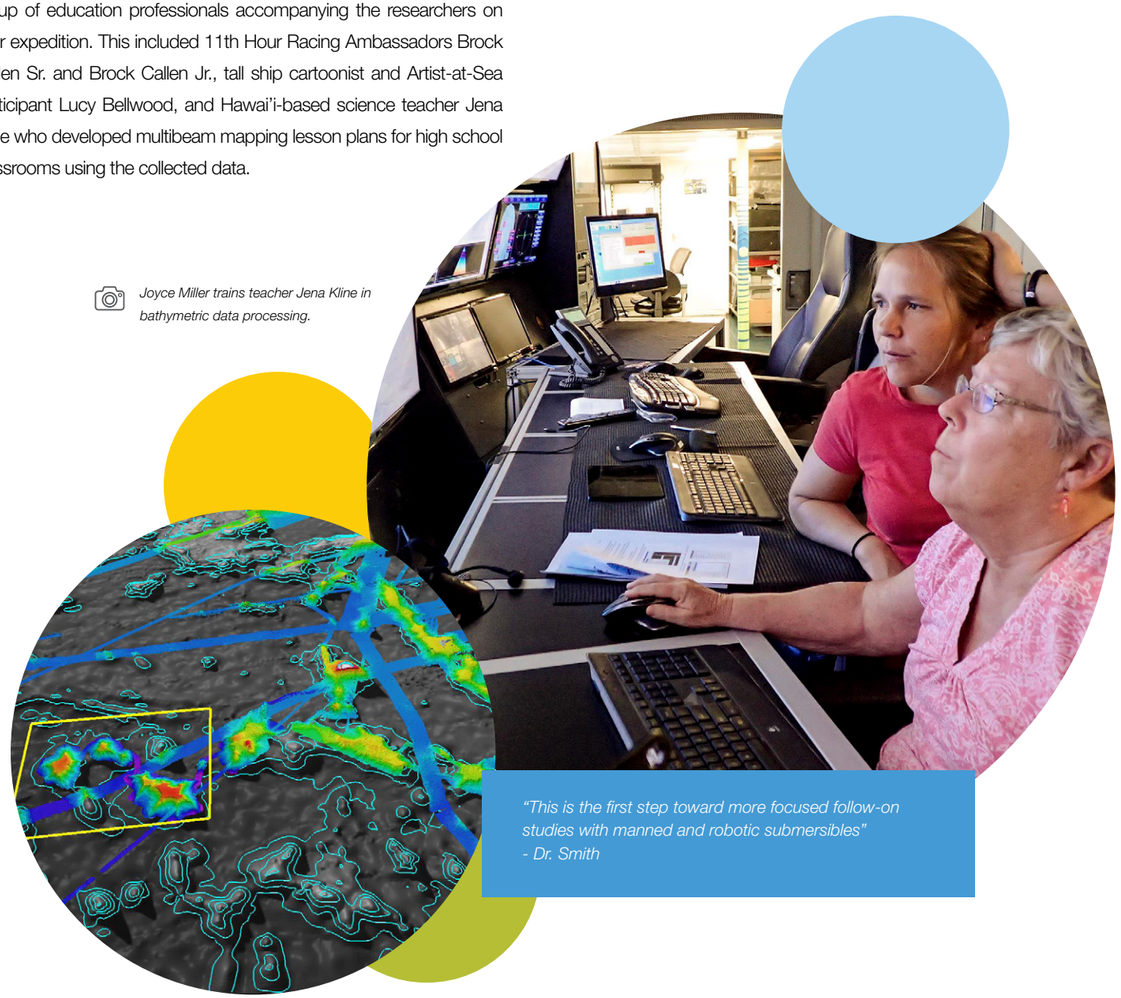
The purpose of these detailed seafloor maps is to help future expeditions characterize the living and non-living resources in this newly protected regions. "This is the first step toward more focused follow-on studies with manned and robotic submersibles," said Dr. Smith.

Using *Falkor*'s onboard multi-beam echosounder processing software, the team was able to compile days of mapping data in real time, unveiling captivating features of the ocean floor, including six previously unmapped seamounts in the southwest corner of the Johnston Atoll Unit. The maps yield valuable insight into the geologic composition of the seamounts. For example, analysis of one of the features, with the proposed name "Edmondson Seamount", demonstrates that it is composed of four distinct and adjacent volcanoes that have continued remodeling in the form of volcanic eruptions, including catastrophic landsliding, and other erosional processes, to coalesce into one large, subsurface mountain.



View of the target mapping area around Johnston Atoll.

Significant efforts were made to share the mapping through a unique group of education professionals accompanying the researchers on their expedition. This included 11th Hour Racing Ambassadors Brock Callen Sr. and Brock Callen Jr., tall ship cartoonist and Artist-at-Sea participant Lucy Bellwood, and Hawai'i-based science teacher Jena Kline who developed multibeam mapping lesson plans for high school classrooms using the collected data.



Joyce Miller trains teacher Jena Kline in bathymetric data processing.

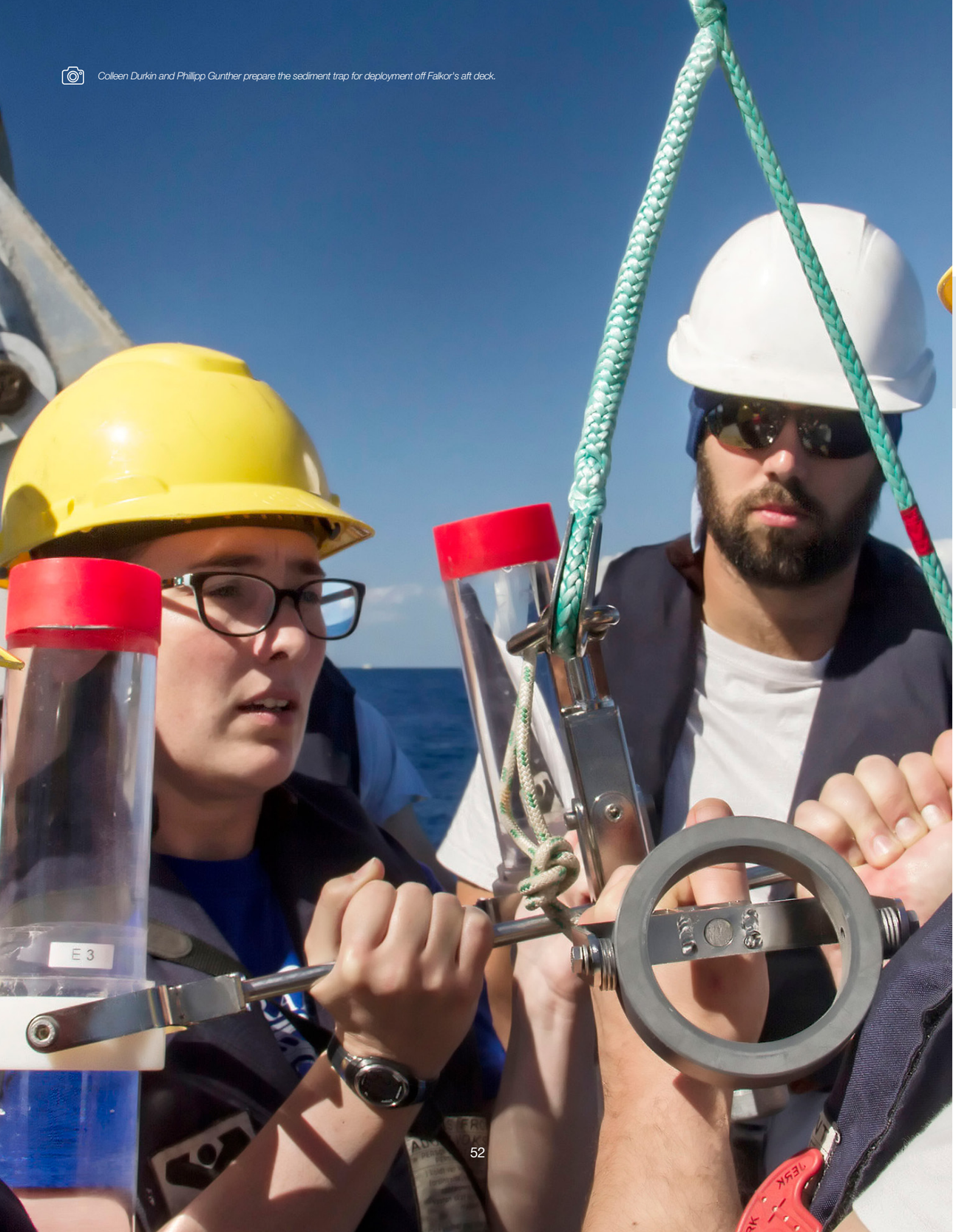
"This is the first step toward more focused follow-on studies with manned and robotic submersibles"
- Dr. Smith

11K

square kilometers of the ocean floor were mapped in high-resolution

High density biological communities and physical resources such as polymetallic crusts and nodules were documented

Dolphins riding Falkor's bow pressure wave.



Colleen Durkin and Phillipp Gunther prepare the sediment trap for deployment off Falkor's aft deck.

SEA TO SPACE
PARTICLE INVESTIGATION

Cruise FK170124 | Jan 24th, 2017 - Feb 20th, 2017

CHIEF SCIENTIST
Dr. Ivona Cetinić

PORT LOCATION
Honolulu - Portland

DOI:
10.7284/907436

LOCATION
Pacific Ocean

COLLABORATING ORGANIZATIONS: NASA Goddard Space Flight Center, Universities Space Research Association, National Science Foundation, Skidmore College, Moss Landing Marine Laboratory, University of Rhode Island, Brown University

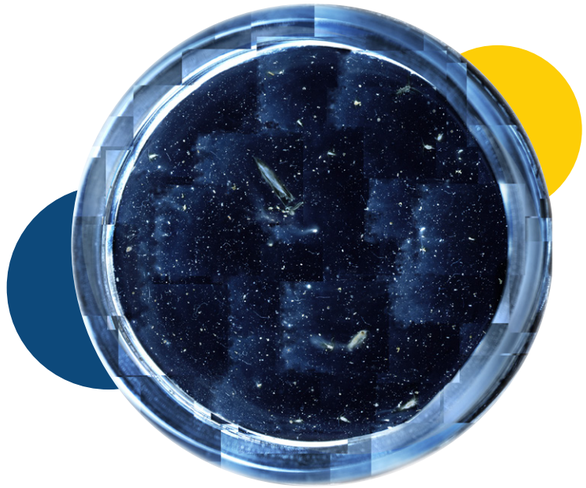
UNDERSTANDING OCEAN COLOR CAN GIVE US INSIGHT INTO THE WATERS BELOW: BOTH BIOLOGICAL AND CHEMICAL ACTIVITIES CAN BE INDICATED THROUGH THE LIGHT AND COLOR REFLECTED BY THE OCEAN'S SURFACE.

Satellite measurements of particle size distributions are essential sources of information as researchers work toward creating models of global processes. However, satellite algorithms for estimating particle size distributions are largely unverified without a lack of confirmed datasets.

Determining the concentration and size of living and nonliving organisms floating in the water, collectively termed “particles”, help to fill in these gaps including identifying dissolved materials and understanding the diversity of plankton within. This is exactly the type of data that was collected on a 25-day expedition aboard *Falkor* in January 2017, under the leadership of Principal Investigator Ivona Cetinić, NASA Universities Space Research Association.

New technology and instruments included a time-lapse sediment trap camera and oxygen based productivity meter, providing imagery and data about particle size distribution. Additionally, the NASA-funded FERPS-particle sizer obtained continuous information about the size of microscopic particles in the ocean for the first time. To quantify phytoplankton growth rates, the multidisciplinary team of oceanographers, engineers, biologists, and computer scientists conducted experiments, measuring the oxygen produced and carbon dioxide consumed over time by the single-celled marine algae. Two different autonomous platforms were deployed, used to capture sinking particles and understand the vertical structure of biology and physics of the ocean.

Using *Falkor*’s high performance computing system allowed the processing of vast quantities of holographic images that were collected with an in situ holographic microscope mounted on the CTD and water sampling frame. The results were virtual reality visualizations that allowed researchers to explore how phytoplankton congregate in relation to each other in a new and very revealing manner.



A composite image containing the findings of one gel sediment trap from the Sea to Space expedition, created from a series of photographs taken with a microscope. Within it, aggregates, fecal pellets, phytoplankton, zooplankton and other particles can be seen.

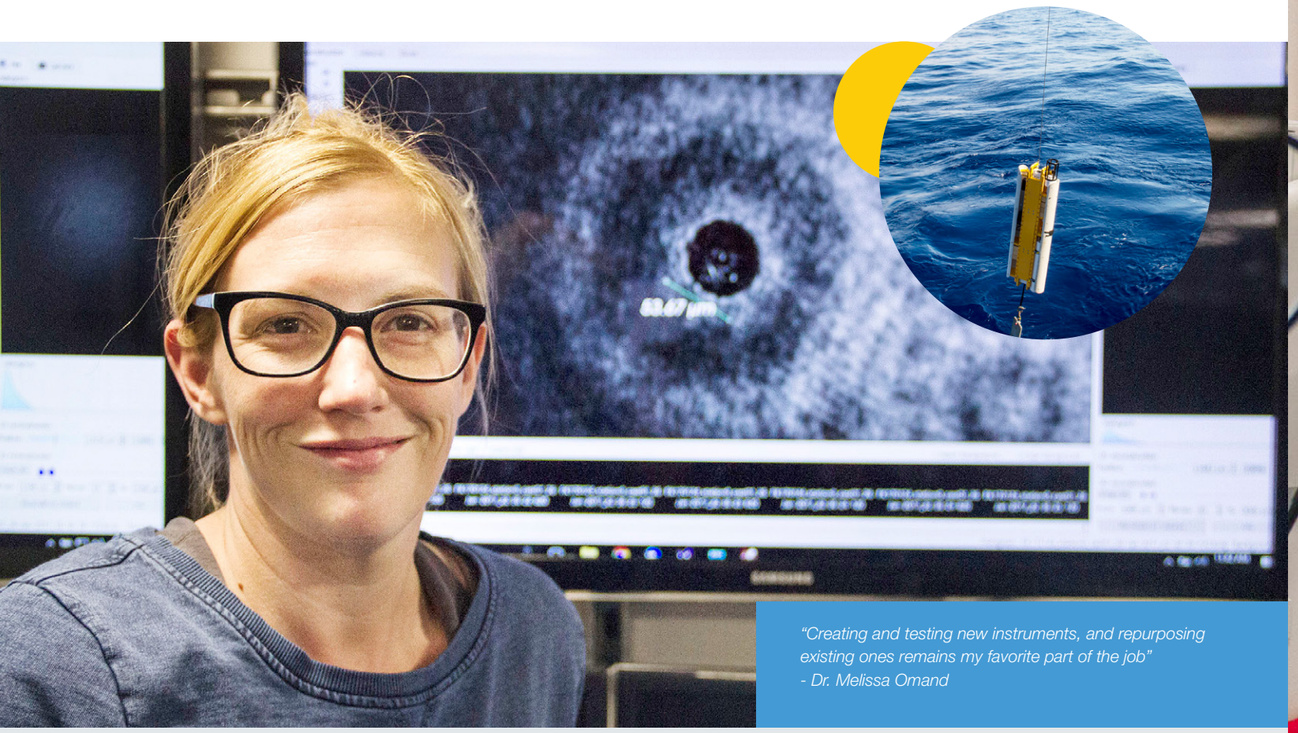
These new in situ instruments provided cutting-edge approaches for the research team to build algorithms upon. The data allowed the science team to make connections between ocean color, diversity of phytoplankton, and the carbon cycle to develop tools to better understand the ocean using satellites and predict future ocean states.

By year 2022, NASA expects to launch the next generation ocean color satellite sensor for the Plankton, Aerosol, Cloud, and Ocean Ecosystem (PACE). This research done aboard *Falkor* will help to develop the PACE sensor that will provide unprecedented detail regarding the color spectrum and intensity of the light exiting the ocean's surface.

This work will move forward possibilities in which scientists can use autonomous vehicles to make measurements in ways - and over scales - that were previously impossible.

Supporting the use of autonomous robotic vehicles and in situ imaging systems to collect data that traditionally requires work-intensive, direct water sampling from ship-based platforms will result in alleviating the effort and cost in future collections, thereby expanding the coverage and duration of observations in the future.

The wire-walker is a sophisticated instrument designed to take numerous measurements from the water column and capture particles falling into the deep ocean while sliding up and down a 150 meter-long wire.

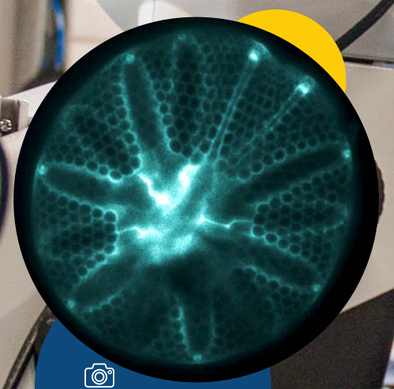


"Creating and testing new instruments, and repurposing existing ones remains my favorite part of the job"
- Dr. Melissa Omand

The idea behind the research was to make a connection between the ocean color, diversity of phytoplankton, and oceanic carbon cycle

New rich data will be used to interpret facts about our oceans, including the diversity, growth, and concentration of phytoplankton, as well as the size of other dissolved organic materials

"By knowing who is in the ocean we can know many other things, such as how is the ocean controlling the climate" - Dr. Ivona Cetinic



Asteromphalus is a centric diatom, broadly oval or circular algae.

Colleen Durkin, oceanographer, studies particle size and distribution in order to relate it to the carbon cycle, as well as the oceans' capacity to store carbon.

Kate Herries, Master's candidate at the University of Hawai'i at Mānoa, and Chief Scientist Ken Rubin get their first look at ancient drowned coral samples collected by ROV SuBastian off Penguin Bank, near the island of Molokai, Hawai'i.

UNRAVELING ANCIENT SEA LEVEL SECRETS

Cruise FK170825 | Leg 1: Aug 25th, 2017 - Sept 5th, 2017 | Leg 2: Sept 11th, 2017 - Sept 27th, 2017

CHIEF SCIENTIST
Dr. Ken Rubin

PORT LOCATION
Honolulu

DOI:
10.7284/907632

LOCATION
Ka'iwi Channel, Penguin Bank, Palmyra Atoll, Kingman reef

COLLABORATING ORGANIZATIONS:
University of Hawai'i at Mānoa, SOEST, University of South Carolina, NOAA Fisheries, Universidad De Puerto Rico

THIS RESEARCH CRUISE WAS REMARKABLE IN THAT THE STUDIES USED THE VERY LATEST TECHNOLOGY IN PIONEERING WAYS TO DISCOVER EVIDENCE OF PAST SEA LEVEL CHANGE IN HAWAI'I AND AROUND THE PACIFIC.

The "Sea Level Secrets" expedition used both autonomous underwater vehicle (AUV) and remotely operated vehicle (ROV) technology to locate and sample ice age coral geological records, gathering data to refine predictions of future sea level rise.

Dr. Ken Rubin, University of Hawai'i, led this two-legged expedition along the central Hawaiian Islands and Line Islands, aimed at discovering and collecting evidence of past sea level change in the South Pacific.

AUV REMUS 600, a specialized vehicle operated by Woods Hole Oceanographic Institution and supported by SOI, served as a robotic sonar mapping platform during the first leg of the expedition, providing information that allowed SOI's ROV SuBastian to be launched for geological mapping and sampling on the second leg.

By using both forms of robotics, the research team was able to collect sonar data, visual documentation, and nearly 184 fossil coral specimens from Penguin Bank, resulting in the first whole-reef reconstruction of an ice age coral reef and using it as an archive of sea level change.

The next step in this project will use artificial intelligence to combine the ultra-high resolution sonar maps with the imagery collected, resulting in a detailed terrain map of the Penguin Bank reef complex and the types of corals that grew there during periods of faster and slower sea level change.

The discovery of drowned ice age coral reefs at Palmyra Atoll and Kingman Reef made it possible to collect samples of ancient fossilized coral skeletons that lived 10,000 to 20,000 years ago.

"Global sea level change is a geographically complex and highly dynamic process that will impact a large fraction of Earth's population in the coming century." - Dr. Ken Rubin

Dr. Ken Rubin works with Terry Naumann in the control room during a dive with ROV SuBastian." to "Dr. Ken Rubin works with Terry Naumann in Falkor's Science Control Room during a dive with ROV SuBastian.

Natalie Summers, a graduate student at the University of Hawai'i, holds a sample of coral brought up by ROV SuBastian during the second leg of the "Sea Level Secrets" research cruise.

These samples are ideal for answering questions of when sea levels changed in the past and how rapidly, especially since they are from an area that is not directly impacted by significant land ice or coastal continental processes. The depth of these drowned reefs also posed a technical challenge for SOI's ROV pilots aboard *Falkor*, who had to adapt to the challenges of shallow water operations, becoming the first team to dive at 100 to 200 meters depth on these reefs.

Ken Rubin of the University of Hawai'i shows genuine excitement at the first viewing of samples of ancient drowned coral collected by ROV SuBastian off Penguin Bank, near the island of Moloka'i, Hawai'i.

First whole-reef reconstruction of an Ice Age coral reef at Penguin Bank, Molokai

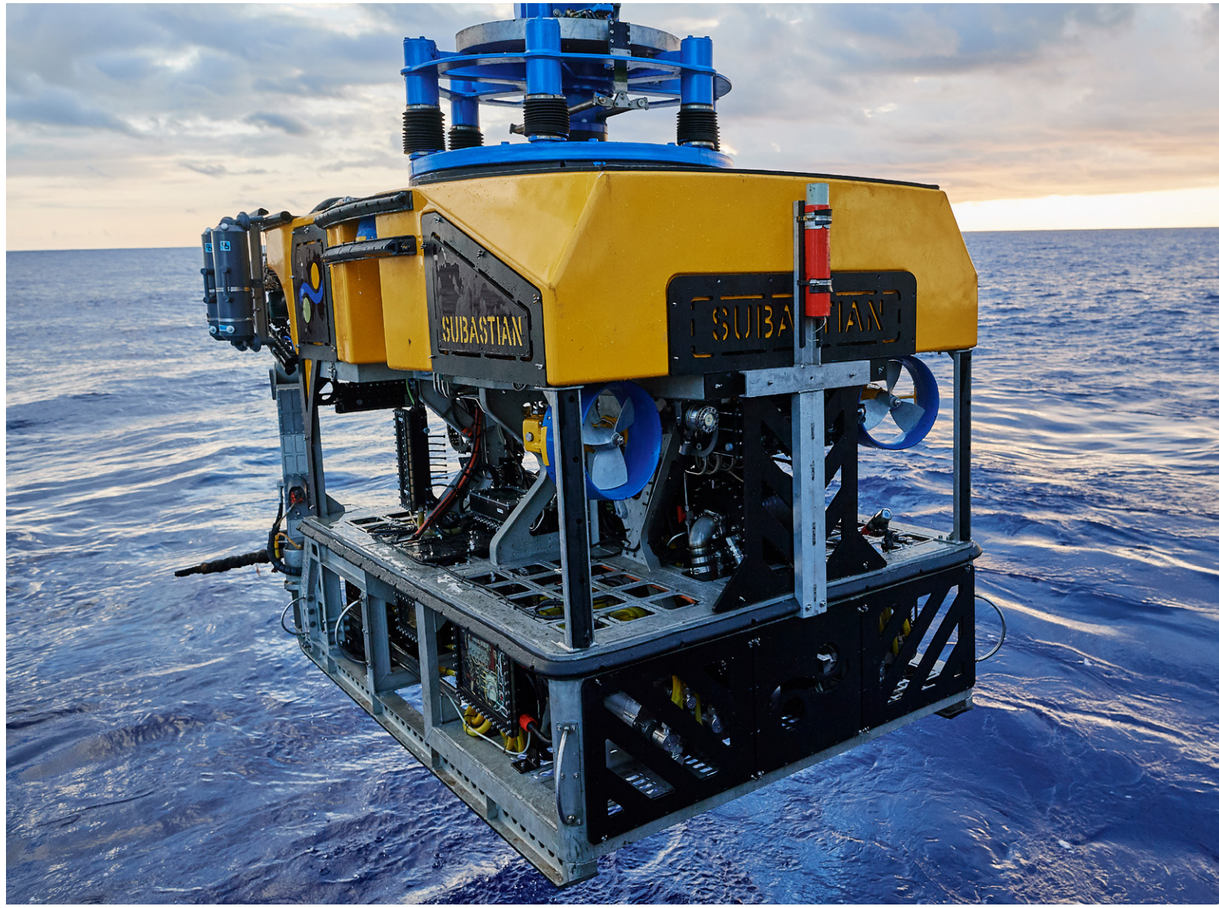
Discovery of drowned Ice Age coral reef at Palmyra Atoll and Kingman Reef

SOI used Squidle+ for the first time after the software was developed expressly to be applied with ROV SuBastian and *Falkor*

Another important achievement on the cruise involved the implementation of the SOI funded Squidle+ software. This software is being developed expressly to be applied with ROV SuBastian and *Falkor*, and is a tool that enables the science team to annotate visual observation records in real-time and in-situ conditions. The software combines all annotations from a dive (and ultimately the cruise), compiling them into a single repository for the scientists to utilize later during analysis of all the data.

Adding more power to the software will give the ability for annotations to be made at any time, by anyone both on the ship and from shore. Sea level rise is a very complex process with many factors, including a variable rate of rise and change that differs by geographic location. The data gathered on this expedition will help us understand sea level rise from the past, which should help us better predict and prepare for the future.

ROV SuBastian is lifted to the aft deck after a successful dive during the second leg of the "Sea Level Secrets" research cruise.



DISCOVERING DEEP SEA CORALS
OF THE PHOENIX ISLANDS

Cruise FK171005 | Oct 5th, 2017- Nov 1st, 2017

CHIEF SCIENTIST
Dr. Erik Cordes

PORT LOCATION
Honolulu - Apia, Samoa

DOI:
10.7284/907641

LOCATION
Phoenix Islands Protected Area

COLLABORATING ORGANIZATIONS:
Temple University, Boston University, Woods Hole Oceanographic Institution, Baruch College, National Oceanic and Atmospheric Administration

THIS WAS THE FIRST EXPLORATION OF THE ISLANDS AND EASTERN SEAMOUNTS OF THE PHOENIX ISLANDS PROTECTED AREA, FOLLOWING THE INITIAL EXPLORATION OF THE WESTERN SEAMOUNTS OF THE TOKELAU RIDGE BY NOAA'S OKEANOS EXPLORER.

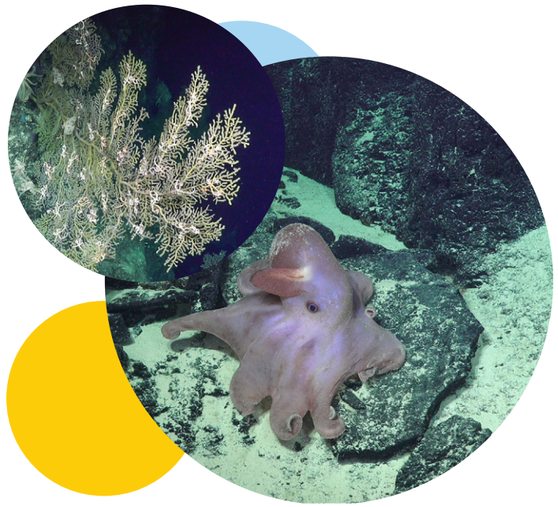
Following the initial exploration of the western seamounts of the Tokelau Ridge by the National Oceanic and Atmospheric Administration's Okeanos Explorer, Dr. Erik Cordes, Temple University, led a team aboard *Falkor* on a first-ever undersea exploration of the eastern seamounts of the Phoenix Islands Protected Area (PIPA), the largest and deepest UNESCO World Heritage site.

Shipboard multibeam mapping and dives using SOI's remotely operated vehicle (ROV) SuBastian revealed the previously unmapped areas surrounding eight unexplored seamounts and islands in high-resolution focus.

This expedition added data from 17 ROV dives, bringing the total of deep-sea dives within PIPA to 25. A combination of deep and shallow ROV SuBastian dives, snorkeling, and previous scuba data formed a complete survey of seamounts from surface to benthos. This enabled researchers to define the zonation of animal communities from the deep sea to the shallow reef for the first time on any seamount.

Sampling efforts were aided by the development of new soft robotics technology, "squishy fingers," developed by the Wyss Institute at Harvard University. This technology was refined during the expedition through testing and SOI's ROV pilot feedback, using 3D printing aboard *Falkor* to fabricate new designs as needed.

The experimental technology is made out of soft and composite materials that surround and grasp delicate objects without destroying them, making previously unobtainable biological samples retrievable.



Victorgorgia soft coral with a chirostylid squat lobster associate in the Phoenix Islands, Kiribati, during the "Discovering Deep Sea Corals in the Phoenix Islands" research cruise. Image made by ROV SuBastian.

Two large Paramuricea coral colonies with numerous brittle star associates at 400 m depth on Orona Atoll within the Phoenix Islands of the Republic of Kiribati during the "Discovering Deep Sea Corals in the Phoenix Islands" expedition. Image made by ROV SuBastian. / A large "dumbo" cirrate octopus on the steep cliffs of Tarina Seamount at approximately 1200 m depth. "Discovering Deep Sea Corals in the Phoenix Islands" research cruise. Image made by ROV SuBastian.

The "squishy fingers" sampling device was developed by the Wyss Institute at Harvard University. During the cruise, Daniel Vogt designed a new version based on the feedback from the ROV pilots, during the "Discovering Deep Sea Corals in the Phoenix Islands" research cruise.

The science team observed, catalogued, and carefully sampled deep-sea corals and their associates from depths exceeding 3,000 meters. Large scleractinian colonies, rare in the deep sea, were observed on pinnacles at multiple sites, associating closely with brittle stars, crinoids, shrimp, crabs, and fish. Over 400 samples of fauna, sediments, and water were collected for genetic, morphological, and chemical analysis. At least two new species of coral and crab were discovered on these unexplored seamounts, and more may be detected through further genetic and morphological analysis.

These data will inform our understanding of deep-sea coral communities, the effect of ocean chemistry on their structure and diversity, as well as the connectivity between seamounts and the shallower reef.

On this expedition new octopus behaviors were observed, illuminating their tight association with corals. For the first time, octopus eggs were seen on coral, juvenile cirrate octopus observed in coral habitat, and three incirrate octopus found within deep-sea coral branches.

+400
samples of fauna, sediments, and water were collected

Highlights included discovering at least two new species of coral and crab, and possibly one ophiuroid

Researchers collected the deep sea specimens by using a new soft robotics technology, known as "squishy fingers"

Researchers observed rare acorn worms, recorded one of the deepest sightings of stomatopod (mantis shrimp), and made multiple sightings of six-gill sharks.

PIPA is fully closed to all extractive and commercial activities, which makes it an ideal place to ask questions about ecological baselines and species distributions in the deep sea. The contributions of high resolution maps, full benthic to surface surveys of species diversity, and 4K video and photographic data will help inform deep-sea science worldwide and contribute to conservation and management of this important world heritage site.

At the beginning of the trip, the team was able to visit the only inhabited Phoenix Island, where they helped repairing tide gauges and enjoyed cultural exchanges - including meals, music, and photographs.

"This journey was in the tradition of the grand research expeditions of the past. We traveled nearly 3,000 miles across the Pacific Ocean and explored a part of the world that has remained entirely hidden from view until now." - Dr. Erik Cordes

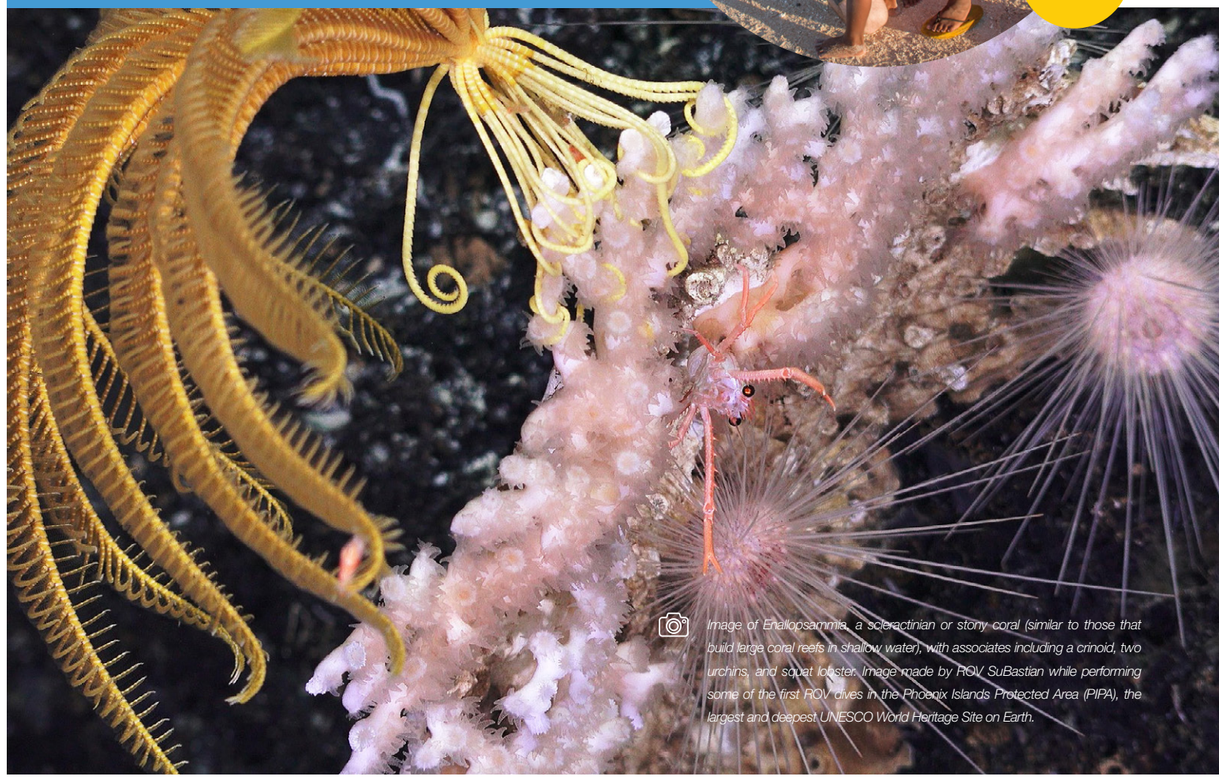


Image of Enallopsammia, a scleractinian or stony coral (similar to those that build large coral reefs in shallow water), with associates including a crinoid, two urchins, and squat lobster. Image made by ROV SuBastian while performing some of the first ROV dives in the Phoenix Islands Protected Area (PIPA), the largest and deepest UNESCO World Heritage Site on Earth.

ROV SuBastian brings in a stunningly-colored sulfide sample from an actively venting complex at the summit of Mata Tolu, an underwater volcano.

UNDERWATER FIRE

STUDYING THE SUBMARINE VOLCANOES OF TONGA

Cruise FK171110 | Nov 10th, 2017 - Dec 17th, 2017

CHIEF SCIENTIST
Dr. Ken Rubin

PORT LOCATION
Apia, Samoa

DOI:
10.7284/907642

LOCATION
Mata Volcano group, The Kingdom of Tonga

COLLABORATING ORGANIZATIONS:
University of Hawai'i at Mānoa, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, GNS, University of Washington, Oregon State University, Point Loma

THE AREA STUDIED IN THIS EXPEDITION IS ONE OF THE MOST ACTIVE UNDERWATER VOLCANO SITES IN THE WORLD, AND IN ITS LIMITED SPACE CONTAINS PERHAPS THE LARGEST NUMBER OF INDIVIDUAL, CLOSELY-SPACED VOLCANOES GLOBALLY.

Falkor's last research cruise of 2017 took place within the Mata Volcano group off the coast of the Kingdom of Tonga, one of the most active volcanic zones in the ocean. The multidisciplinary expedition team led by Dr. Ken Rubin, University of Hawai'i, traveled to this remote region to investigate volcanic eruptions and their impacts on ocean chemistry and ecosystems using robotic technology.

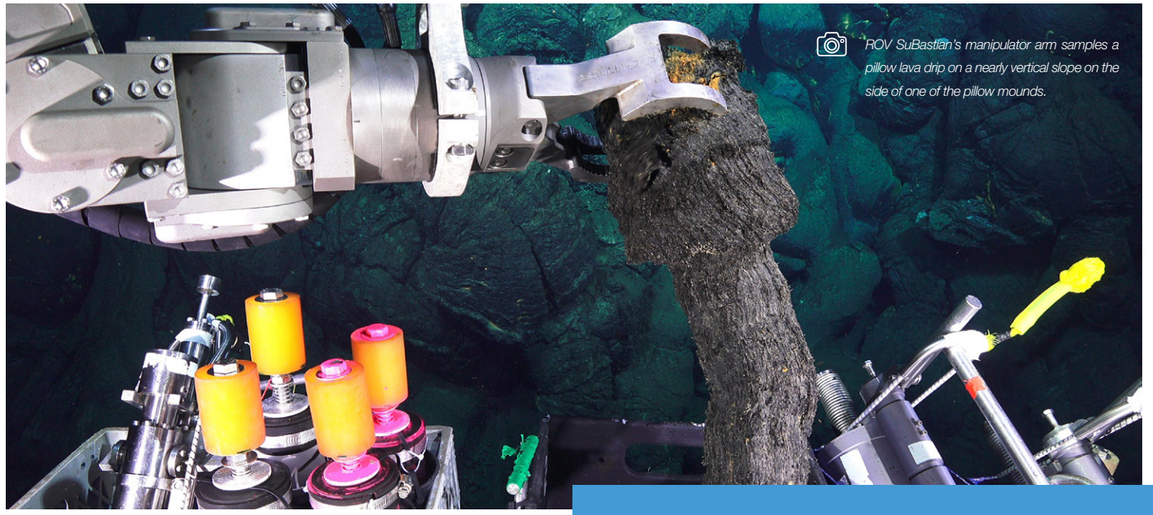
During the first leg of the expedition, the United States National Science Foundation's autonomous underwater vehicle (AUV) *Sentry*, operated by Woods Hole Oceanographic Institution and supported by SOI, was used to conduct sonar mapping, producing the first high-resolution maps for much of the area. The AUV was also used to take a closer look at landforms of recent changes, to photograph the sea floor, and to measure water column properties; this was augmented by water column mapping and sampling via CTD. SOI's ROV SuBastian completed 21 dives on leg two, allowing for close investigation of volcanic vents, structures, lava flows and explosive deposits, fluid venting sites, and both vent and non-vent biology.

Using ROV SuBastian, the science team located ten recently-erupted volcanic deposits at two volcanoes, and explored six volcanoes for the first time, where they discovered three new hydrothermal vent chimney systems. Rock, sediment, biological, and water samples were taken from a range of vents, chimneys, and eruption deposits.

Other highlights include retrieving samples of extremely rare volcanic rock types and closely exploring the largest known dacite lava flows on Earth. The team also used newly developed tools on the ROV to optimize recovery of coarse volcanic sediments and third-party team coordination software to interact in real-time with shore-based members of the science team.

"Submarine volcanism is one of the fundamental processes that has affected the composition of the oceans, the shape of seabed, and the development of life on our planet."
- Dr. Ken Rubin

Crew recovers ROV SuBastian back onto the aft deck of Falkor. Extensive volcanic sands were seen during the expedition. This image shows bits of pillow lava poking through copious quantities of volcanoclastic sands produced during eruption that occurred within the last year near the summit of West Mata Volcano.



ROV SuBastian's manipulator arm samples a pillow lava drip on a nearly vertical slope on the side of one of the pillow mounds.

The chemical and biological analyses of collected samples will take some time, but important discoveries were made well before the cruise ended. The team showed that recent eruptions were not restricted to the summit zones of volcanoes, providing new insights into eruption styles, magma plumbing systems, and how Mata volcanoes have grown over time. One surprise of the expedition was widespread evidence of deep sea explosive volcanism. Water pressure in the deep sea should restrict explosive eruptions, but the evidence gathered through eruption deposits tells a different and very intriguing story.

Most of Earth's volcanoes are deep undersea, making them difficult to detect and study, yet fundamental to understanding the formation of Earth and the composition of our oceans. Acquiring basic knowledge about eruption styles, sizes, rates, and their relationships to ocean chemistry and benthic ecology is vital to our understanding of the planet.

17 ROV DIVES WERE STREAMED

All of the ROV dives were streamed live, attracting thousands of viewers each day to SOI's YouTube and Facebook Live channels. Over 17 days worth of high resolution video from the expedition's dives is now publicly available online

The discoveries made on this expedition not only inform us about an area with the largest number of individual, closely-spaced volcanoes in the world (30 volcanoes in a 50x50 km area), but have far-reaching implications for our overall understanding of how volcanoes work, what minerals they contain, what animals they support, what hazards they may present, and their role in overall oceanic chemistry. The multidisciplinary focus of this expedition allowed unprecedented investigation into the interrelated aspects of submarine volcano geology, biology, and chemistry.

+470
biological samples

+60
vent fluid samples

+250
rock samples

One highlight of the expedition was the discovery of three new hydrothermal venting sites. Here a "black smoker" chimney releases hydrothermal fluid into the deep sea.

Falkor's crew and researchers recover AUV REMUS 600 from a mapping mission over Penguin Bank. The workboat is used by the crew to find and tow the AUV into a position where a tagline and crane from the ship can be connected to stabilize and bring the vehicle aboard.

2017 SCIENTIFIC
PUBLICATIONS

Anderson, M., Chadwick, Jr., W., Hannington, M., Merle, S., Resing, J., Baker, E., Butterfield, D., Walker, S., and N. Augustin. (2017). Geological Interpretation of Volcanism and Segmentation of the Mariana Back-arc Spreading Center between 12.7°N and 18.3°N, Geochem. Geophys. Geosyst., 18, doi:10.1002/2017GC006813.

Anderson, R., Reveillaud, J., Reddington, E., Delmont, T., Eren, A., McDermott, J., Seewald, J., and J. Huber. (2017). Genomic Variation in Microbial Populations Inhabiting the Marine Subseafloor at Deep-sea Hydrothermal Vents. Nature Communications 8, 1114, doi: 10.1038/s41467-017-0122806.

Baker, E., Walker, S., Resing, J., Chadwick, Jr., W., Merle, S., Anderson, M., Butterfield, D., Buck, N., and S. Michael. (2017). The Effect of Arc Proximity on Hydrothermal Activity Along Spreading Centers: New Evidence from the Mariana Back-arc (12.7° - 18.3°N). Geochem. Geophys. Geosyst., Accepted Author Manuscript, Doi: 10.1002/2017GC007234.

Chu, J., and K. Gale. (2017). Ecophysical Limits to Aerobic Metabolism in Hypoxia Determine Epibenthic Distributions and Energy Sequestration in the Northeast Pacific. Limnology and Oceanography 62:59 - 74, doi: 10.1002/lno.10370.

Etnoyer, P., Wagner, D., Fowle, H., Poti, M., Kinlan, B., Gerogian, S., and E. Cordes. (2017). Models of Habitat Suitability, Size, and Age-class Structure for the Deep-sea Black Coral leiopathes Glaberrima in the Gulf of Mexico. Deep Sea Research Part II: Topical Studies in Oceanography, in press, doi: 10.1016/j.dsr2.2017.10.1008.

Fortunato, C., Larson, B., Butterfield, D., and J. Huber. (2017). Spatially Distinct, Temporally Stable Microbial Populations Mediate Biogeochemical Cycling At and Below the Seafloor in Hydrothermal Vent Fluids. Environmental Microbiology, doi: 10.1111/1462-2920.14011.

Gartman, A., Hannington, M., Jamieson, J., Peterkin, B., Garbe-Schoenberg, D., Findlay, A., Fuchs, S., and T. Kwasnitschka. (2017). Boiling-induced Formation of Colloidal Gold in Black Smoker Hydrothermal Fluids. Geology 46(1); 39-42, doi:10.1130/G39492.1.

Gerringer, M., Linley, T., Jamieson, A., Goetze, E., and J. Drazen. (2017). Pseudoliparis swirei sp. nov.: A Newly-discovered Hadal Snailfish (Scorpainiformes: Liparidae) from the Mariana Trench, Zootaxa 4358:1, doi: 10.11646/zootaxa.4358.1.7.

Gerringer, M., Drazen,J., and P. Yancy. (2017). Metabolic Enzyme Activities of Abyssal and Hadal Fishes: Pressure Effects and a Re-evaluation of Depth-related Changes. Deep-Sea Research Part I: Oceanographic Research Papers, 125:135-146, doi:10.1016/j.dsr.2017.05.010.

Gerringer, M., Popp, B., Linley, T., Jamieson, A., and J. Drazen. (2017) Feeding Ecology of Hadal Fishes; Comparative Analyses of Stomach Contents and Compound Specific Stable Isotopes of Individual Amino Acids. Deep-Sea Research Part I: Oceanographic Research Papers 121:110-120, doi:10.1016.j.dsr.2017.01.003.

Jamieson, A., Malkocs, T., Piertney, S., Fujii, T., and Z. Zhang. (2017). Bioaccumulation of Persistent Organic Pollutants in the Deepest Ocean Fauna. Nature Ecology & Evolution, 1:0051, doi:10.1038/s41559-016-0051.

Khanna, P., Droxler, A., Nittrouer, J., Tunnell, Jr., J., and T. Shirley. (2017). Coralgal Reef Morphology Records Punctuated Sea-level Rise During the Last Deglaciation. Nature Communications 8, 1046, doi: 10.1038/s41467-017-00966-x.

Lan, Y., Sun, J., Tain, R., Bartlett, D., Li, R., Wong, Y., Zhang, W., Qiu, J., Xu, T., He, L., Tabata, H., and P. Qian. (2017). Molecular Adaptation in the World's Deepest-living Animal: Insights from Transcriptome Sequencing of the Hadal Amphipod Hirondellea gigas. Mol. Ecol. 26:14, dOI: 10.1111/mec.14149.

Linley, T., Stewart, A., McMillan, P., Clark, M., Gerringer, M., Drazen, J., Fujii, T., and A. Jamieson. (2017). Bait Attending Fishes of the Abyssal Zone and Hadal Boundary: Community Structure, Functional Groups and Species Distribution in the Kermadec, New Hebrides and Mariana Trenches. Deep-Sea Research Part I: Oceanographic Research 121:38-53, doi:10.1016/j.dsr.2016.12.009.

Omand, M., Cetinić, I., and A. Lucas. (2017). Using Bio-optics to Reveal Phytoplankton Physiology from a Wirewalker Autonomous Platform. Oceanography 30(2): 128 - 131, doi: 10.5670/oceanog.2017.323.

Orcutt, B., Lapham, L, Delaney, J., Sarode, N., Marshall, K., Whaley-Martin, K., Slater, G., Wheat, C., and P. Girguis. (2017). Microbial Response to Oil Enrichment in Gulf of Mexico Sediment Measured Using a Novel Long-term Benthic Lander System. Elem. Sci. Anth., 5(18), doi: 10.1525/elementa.129.

Rahlff, J., Stolle, C., & Wurl, O. (2017). SISI: A New Device for In Situ Incubations at the Ocean Surface. Journal of Marine Science and Engineering, 5(4), 46; doi:10.3390/jmse5040046.

Singh, S., Hananto, N., Qin, Y., Leclerc, F., Avianto, P., Tapponier, P., Carton, H., Wei, S., Nugroho, A., Gemilang, W., Sieh, K., and S. Barbot. (2017). The Discovery of a Conjugate System of Faults in the Wharton Basin Intraplate Deformation Zone, Science Advances 2017, 3:1, doi: 10.1126/sciadv.1601689.

Streich, M., Ajemian, M., Wetz, J., and G. Stunz. (2017). A Comparison of Fish Community Structure at Mesophotic Artificial Reefs and Natural Banks in the Western Gulf of Mexico, Marine and Coastal Fisheries, 9 (1), doi:10.1080/19425120.2017.1282897.

Watson, S., Whittaker, J., Lucieer, V., Coffin, M., and G. Lamarche., (2017). Erosional and Depositional Processes on the Submarine Flanks of Ontong Java and Nukumanu Atolls, Western Equatorial Pacific Ocean, Marine Geology 392: 122-139, doi: 10.1016/j.margeo.2017.08.006.

Wurl, O., Ekau, W., Landing, W., and C. Zappa. (2017). Sea Surface Microlayer in a Changing Ocean - A Perspective. Elem. Sci. Anth., 5:31, doi: 10.1525/elementa.228.

In the waters off Tonga, ROV SuBastian allowed researchers to observe a multitude of life in the deep sea, including Gorgonian coral with associate brittle stars (facing page) and hydrothermal vent colonies of snails, crabs, and mussels (this page).

Close-up detail image of diffuse flow hydrothermal activity through volcanic sands deposited in the 2016-2017 eruption at West Mata Volcano, showing microbial mat structures (orange) and other vent organisms.

2017 SCIENTIFIC
PRESENTATIONS

Anderson, M., Chadwick, Jr., W., Merle, S., Resing, J., Baker, E., Walker, S., Hannington, M., and N. Augustin. (2017). Relationship between Tectonism, Volcanism, and Hydrothermal Venting along the Mariana Back-arc Spreading Center between 12.7N and 18.3N. Oral Presentation at AGU Chapman Conference on Submarine Volcanism, Hobart, Tasmania, AUS.

Bosak, S., et al. (2017). Phytoplankton Species Composition Contributing to Carbon Export - Sea to Space Particle Investigation. Poster Presentation at 11th International Phycological Congress, Szczecin, POLAND.

Brandon, J., Freibott, A., Taylor, A., and M. Ohman. (2017). The Abundance and Distribution in the California Current and the North Pacific Subtropical Gyre, Imaged with a Novel Method. Poster Presentation at ASLO Meeting, Honolulu, HI, USA.

Cetinić, I., et. al. (2017). Sea to Space Particle Investigation. Poster Presentation at Ocean Carbon Biogeochemistry Summer Workshop, Woods Hole, MA, USA.

Cetinić, I., et. al. (2017). Sea to Space Particle Investigation Expedition in the Pacific. Invited Lecture to NASA Goddard Space Flight Center, Sciences and Exploration Directorate Greenbelt, MD, USA.

Cetinić, I., et. al. (2017). Sea2Space. Invited Colloquium to NASA Goddard Space Flight Center, Education and Communication Greenbelt, MD, USA.

Chadwick, Jr. W. From Galapagos to Mariana: Discovering the Diversity of Hydrothermal Vent Environments, Oral Presentation at OSU and Hydrothermal Vents: 40th Anniversary of the Discovery that Launched 1000 Ships, Corvallis, OR, USA.

Chadwick, Jr., W., Merle, S., Kaiser, C., Baker, E., Walker, S., Resing, J., Butterfield, D., Baumberger, T., Anderson, M., Shore, P., Wiens, D., and Rubin, K. (2017). A Recent Volcanic Eruption Discovered on the Central Mariana Back-arc Spreading Center. Oral Presentation at IAVCEI 2017 General Assembly, Portland, OR, USA.

Du Preez, C. and C. Fisher. (2017). Remarkable Decadal Stability at Lau Basin Hydrothermal Vents (Southwest Pacific). Oral Presentation at 6th International Symposium on Chemosynthesis-Based Ecosystems, Woods Hole, MA, USA.

Du Preez, C. (2017). Deep Sea Exploration: Filming Battles, Behavior, Bangs, & Bacon. Invited Lecture to Harvard University, Cambridge, MA, USA.

Du Preez, C., and C. Fisher. (2017). Monitoring Spatial and Temporal Variability at Hydrothermal Vents: A Decade of Repeated Centimeter-scale Mapping. Oral Presentation at Marine Imaging Workshop, Kiel, GERMANY.

Durkin, C., et al. (2017). Linking Surface Phytoplankton with Sinking Particles. Poster Presentation at CLIVAR/OCB Ocean Hotspots Workshop, Moss Landing, CA, USA.

Durkin, C. (2017). Linking Phytoplankton with Sinking Particles and Carbon Export. Invited Lecture to University of California Santa Cruz, Santa Cruz, CA, USA.

Durkin, C., et. al. (2017). Linking Surface Phytoplankton with Sinking Particles. Poster Presentation at Ocean Carbon Biogeochemistry Summer Workshop, Woods Hole, MA, USA.

Estapa, M., et al. (2017). Optical Attenuance-based Measurements of Sinking Carbon Particles: Are Different Detectors Quantifying the Same Thing? Oral Presentation at Gordon Research Conference in Chemical Oceanography, New London, NH, USA.

Khanna, P., Droxler, A., Nittrouer, J., Tunnell, W., and T. Shirley. (2017). Late Quaternary Transgressive Coralgal Reef Growth Along the South Texas Continental Shelf Edge. Oral Presentation at Industry Rice Earth Science Symposium, Houston, TX, USA.

Knorlein, B. (2017). From Sea to Space: Application of Virtual Reality in Science. Invited Lecture to NASA Goddard Space Flight Center, Greenbelt, MD, USA.

Ljubešić, Z.. (2017). From Microscopes to Telescopes. Invited Lecture to University of Zagreb, Zagreb, CROATIA.

Ljubešić, Z. (2017). Development of Methods for the Phytoplankton Research in the Adriatic Sea. Invited Lecture to Croatian Academy for Sciences and Arts, Zagreb, CROATIA.

Omand, M. (2017). Diel Rhythms in Phytoplankton Physiology and Marine Snow Export Observed from a Wirewalker Autonomous Platform. Invited Lecture to Rutgers University, New Brunswick, NJ, USA.

Omand, M. (2017). Diel Rhythms in Phytoplankton Physiology and Marine Snow Export Observed from a Wirewalker Autonomous Platform. Invited Lecture to University of Rhode Island, Narragansett, RI, USA.

Omand, M. (2017). Carbon Export Processes at Meso- and Submesoscales. Invited Lecture at Ocean Carbon Biogeochemistry Summer Workshop, Woods Hole, MA, USA.

Schollaert Uz, S. (2017). Microscopic Life in a Moving Ocean. Invited Lecture to Baltimore Science Fiction Convention, Baltimore, MD, USA.

Shelley, R., Wyatt, N., and W. Landing. (2017). Trace Elements in Aerosols, Rain, and the Sea-Surface Microlayer of the South Pacific Ocean Under Low Wind Conditions. Oral Presentation at 2017 Goldschmidt Conference, Paris, FRANCE.

Shelley, R., and W. Landing. (2017). Trace Elements in Aerosols, Rain, and the Sea-surface Microlayer of the South Pacific Ocean Under Low Wind Conditions. Oral Presentation at Gordon Research Conference in Chemical Oceanography, New London, NH, USA.

Smith, J., and J. Tree. (2017). Enormous Rift Zones, Giant Landslides, and Ubiquitous Paleo-reef Terraces: Detailed Submarine Geologic Mapping Reveals Complexity of the Northwestern Hawaiian Ridge. Oral Presentation at Geological Society of America, Honolulu, HI, USA, doi: 10.1130/abs/2017CD-292709.

Tree, J., Smith, J., Miller, J., and A. Kang. (2017). Detailed Geological Mapping Exposes Complex Eruptive History and Fundamentally Different Relative Ages of Newly Surveyed Seamounts within the Johnston Atoll Unit of the Pacific Remote Islands Marine National Monument Oral Presentation at Geological Society of America, Honolulu, HI, USA, doi: 10.1130/abs/2017CD-292568.

Trotter, J., Sadekov, A., Montagna, P., and M. McCulloch. (2017). Elemental Systematics of Modern and Fossil Deep Water Corals from the Perth Canyon, Australia. Oral Presentation at 2017 Goldschmidt Conference, Paris, FRANCE.

Walcutt, N., Knorlein, B., Sgouros, T., and M. Omand. (2017). Bringing Planktonic Holograms to Life with the YURT Ultimate Reality Theatre. Poster Presentation at Rhode Island EPSCoR Research Symposium, Providence, RI, USA.

Walcutt, N., et. al. (2017). Assessment of Holographic Microscopy for Quantifying Marine Particles. Poster Presentation at Ocean Carbon Biogeochemistry Summer Workshop, Woods Hole, MA, USA.

Wurl, O., Ribas Ribas, M., Landing, W., and C. Zappa. (2017). Surface Skin Salinity - First in situ Measurements in the Tropical Ocean. Oral Presentation at Global Ocean Salinity Workshop, Woods Hole, MA, USA.

Wurl, O., Bird, K., Cunliffe, M., Landing, W., Mustaffa, N., Ribas Ribas, M., and C. Zappa. (2017). Warming and Freshening of the Sea Surface by Trichodesmium sp. Oral Presentation at International Workshop: Harmful Algal Blooms: Unifying Insights from Lab Experiments, Field Monitoring and Modeling, Delmenhorst, GERMANY.

STUDENT THESES/DISSERTATIONS

Oeljeschläger, L. (2017). Chemical Composition of Dissolved Organic Matter (DOM) of the Sea Surface Microlayer in the Indo-Pacific Ocean. Masters of Science Thesis at the University of Oldenburg.

Rahlff, J. (2017). The Role of Microbial Communities at the Sea Surface in Air-sea Gas Exchange. Doctorate Thesis at the University of Oldenburg.

Visic, H. (2017). Chemotaxanomic and Morphological Approach to Phytoplankton Analyses in Contrasting Trophic Systems of North Pacific. Masters of Science Thesis at the University of Zagreb.

Children explore Falkor's Science Control Room while touring the ship in Honolulu.

PHOTO CREDITS

Cover	Steve Constable
Cover	Kirsten Carlson
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Cover	Mónica Naranjo González
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The research team and Falkor crew from the "Discovering Deep Sea Corals of the Phoenix Islands" gather on the bow for a group shot via quadcopter.

View of new propeller after Falkor's 2017 drydock period.

COLLABORATORS
2017

11th Hour Racing
University of Hawai'i
Baruch College, The City University of New York
Boston University
NOAA
The Arts at Marks Garage
Temple University
Woods Hole Oceanographic Institution 1930
NASA Goddard Space Flight Center
Universitas Studiorum Zagrabiensis MDCLXIX
Brown
Duke University
GNS Science Te Pū Ao
Grey Bits Engineering
PMEL
OSU Oregon State University
Iolani School
GSO
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Moss Landing Marine Laboratories
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Bishop Museum
Sail Newport
Point Loma Nazarene University
Waikiki Aquarium, University of Hawai'i
Exploring by the Seat of Your Pants, Question | Explore | Conserve
University of South Carolina
Universidad de Puerto Rico 1903
NOAA Fisheries

Enallopsammia (a stony coral) with associates including a squat lobster, a crinoid, and an urchin.

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2017 | ANNUAL REPORT

5 YEARS OF SCIENCE ABOARD *FALKOR*

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