Monterey Bay Aquarium Research Institute

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November 15, 2020

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RE: Monterey Accelerated Research System (MARS): Projects Report
Permit # MBNMS-2007-030-A11

Dear Sophie, Mark, and Ken,

Enclosed please find the 2020 MARS Summary Report. Many activities in 2020 were similar to the prior year with previously approved projects utilizing the cable system.

While some efforts were delayed due to shutdowns from the COVID-19 pandemic, other deployments continued and saw success. There are no new projects proposed to be deployed on MARS in 2021, although there are some modifications to existing projects. The very successful Soundscape Research and Education project is looking to collaborate further with the Naval Postgraduate School to add an additional passive acoustic hydrophone for further refinement of directionality data. In addition, some modifications planned for 2020 will take place in 2021 instead, such as sensor additions and upgrades for the Quest Foundation's Ocean Discovery Platform. We are also happy to include in this report that we recently completed and submitted the 2020 MARS cable monitoring survey report to each of the agencies. Further details regarding these and all current plans on MARS for 2021 are included in the report.

As a refresher, this report is organized with the following information:

Project Status Summaries
A summary is included for each project that has been or planned to be deployed on MARS in 2020. Each summary contains activities that occurred in 2020, as well as any planned deployments for 2021.

Other Approved Projects
The report includes a summary page of approved projects that have yet to go on MARS, or projects that have been deployed previously and may be deployed again in the future.

Deployment Summary Spreadsheet
This spreadsheet contains additional details about 2020 activities summarized in one spreadsheet for easy reference.

Please let us know if you have any questions regarding modifications to plans or if we need to take any further steps to seek approval. All work will occur in Federal waters, and we believe there is minimal environmental impact associated with these deployments.

As always, we are very appreciative of all the assistance and support you have given us with this project. Please feel free to contact me at 831-775-1885 or mandy@mbari.org to discuss this further or if you have any questions or need additional information.

Best regards,

Mandy Allen

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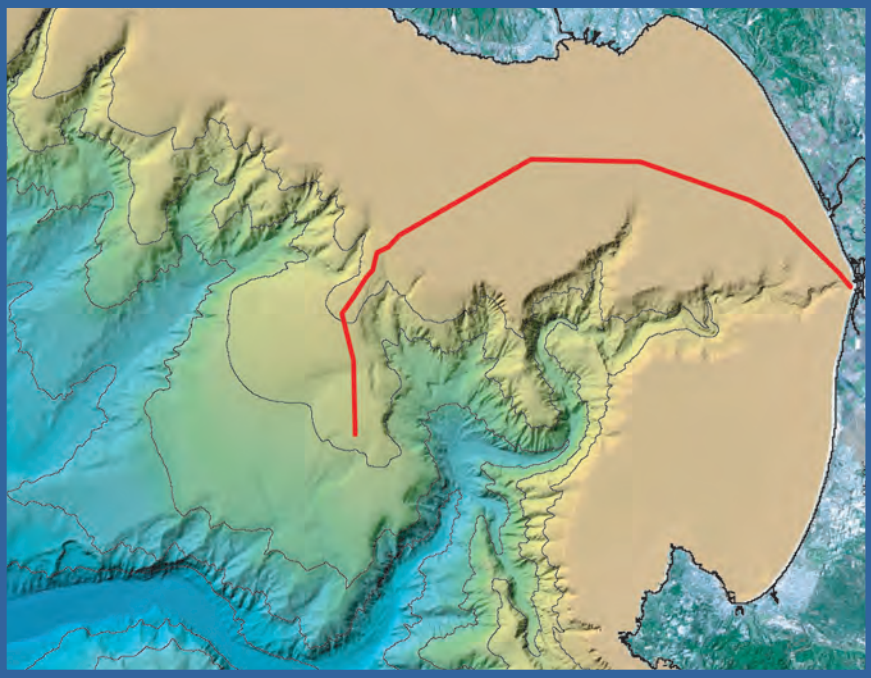
Monterey Accelerated Research System (MARS)

2020 Summary Report
Permit # MBNMS-2007-030-A11



M B A R I

Monterey Bay Aquarium Research Institute

Submitted November 2020

Soundscape Research and Education

(formerly *Passive Acoustic Sensing in Foraging Ecology Research*)

Principal Investigator: John Ryan, MBARI

Purpose

The overarching purpose is to investigate the MBNMS soundscape using passive acoustic monitoring (PAM) through a hydrophone installed on the MARS cabled observatory (Figure 1). We aim to understand (a) the presence and activity of marine mammals, (b) relationships of mammal vocal activity to ecosystem variation, and (c) the nature and consequences of anthropogenic noise. The education objective is to enrich educational programs and media with soundscape recordings and scientific content.

Figure 1. A hydrophone on the MARS cabled observatory is revealing the nature of acoustic habitat in the heart of Monterey Bay National Marine Sanctuary. The location of a Sound Surveilance System (SOSUS) array used in prior sound research is also shown.

Methods

Research methods involve data acquisition—recording sound through a hydrophone on the MARS observatory and data analysis—using signal processing and machine learning to identify specific sound sources and their variations in time. Educational content development involves collaborative work with NOAA and other organizations.

Deployments

The original hydrophone was deployed on July 28, 2015. The deployment involved connection of a 70-m extension cable between the MARS cabled observatory and the hydrophone. The deployment location is north of MARS at 36.7128°N, 122.186°W. The hydrophone is housed in a small tripod made of galvanized steel pipe (tripod footprint is approximately 0.25 m^2). Environmental consequences for such a small instrument deployment are anticipated to be extremely minimal, and the passive acoustic monitoring (listening) itself will have no impact on the environment or inhabitants. The originally deployed hydrophone was replaced on June 23, 2017 with an exact replicate of the original system. A second hydrophone was added to the MARS observatory in February 2019. This hydrophone, owned by NPS, added a valuable capability to PAM research: the ability to determine the direction of the sound source. This hydrophone is suspended within a metal frame that has a seafloor footprint of approximately 0.5 m^2. The deployment location is south of MARS at 36.7121°N, 122.187°W.

Activities in 2020

A study integrating MARS recordings and tag-based metrics from individual whales revealed that the balance of foraging and migration is reflected in day/night patterns of blue whale singing (Oestreich et al., 2020). The newly discovered acoustic signature of migration may be an important tool for protection, for example to provide early warning of migrating whales entering regions with intensive shipping activity. The directional hydrophone [data managed by the Naval Postgraduate School (NPS) in Monterey] is now enabling spatial tracking of calls from blue and fin whales, both endangered species, toward better understanding their regional presence and patterns of habitat occupancy. Odontocete research from passive acoustic sensing is occurring in collaboration with MBARI researchers using MARS active acoustic sensing to examine forage species and predator-prey interactions, and it is the basis of a student group project in machine learning at California Polytechnic State University. Ongoing work using machine learning is examining how humpback song structure changes through time, as a window in this aspect of the species' cultural transmission.

Chronic and acute impacts of anthropogenic noise on ocean life, particularly marine mammals, is a growing resource management priority within NOAA. The MARS hydrophone has revealed the patterns of noise from small explosives used in fishing operations, so called "seal bombs" (Simonis et al., 2020). The explosion noise is prevalent during part of the year, and model study reveals that this noise propagates far from the source (tens of kilometers), with implications for the protection of acoustically sensitive species. Another noise study enabled by MARS concerns COVID impacts on low-frequency ocean noise, through slowing of ocean transportation activity. Analysis of MARS sound recordings in this study (Ryan et al., in prep.) is supported by analysis of regional vessel traffic using Automatic Identification System (AIS) data, as well as coastwide and basin-scale data from the US Department of Transportation (in collaboration with NOAA).

Following successful installation of an exhibit at the NOAA Sanctuary Exploration Center in Santa Cruz in 2019, a second public exhibit is now being built by MBARI for the San Simeon Visitor Center, a collaboration between NOAA and California State Parks. To enable global access to ocean sound recorded through MARS, MBARI developed three resources: (1) a listening library of identified and described sounds, (2) a live stream from MARS, and (3) an Alexa skill that provides access to both the library and live stream (https://www.mbari.org/soundscape-listening-room/).

Plans for 2021

The two existing hydrophones, one omnidirectional and one directional, will remain deployed on MARS during 2021 for continuing support of research and educational goals. Additionally, we plan to deploy a second directional hydrophone in collaboration with NPS that will enhance spatial localization of marine mammal species and noise sources. While being connected to MARS via a junction box and extension cable, this new hydrophone will reside 3 km from MARS, at the established Monterey Ocean-Bottom Broadband (MOBB) Seismometer site (https://www.mbari.org/at-sea/cabled-observatory/mars-science-experiments/mars-mobb/).

Monterey Ocean Bottom Broadband (MOBB) Seismometer
Principal Investigator: Barbara Romanowicz, MBARI Adjunct, UC Berkeley

Status of Project

The Monterey Ocean Bottom Broadband (MOBB) observatory had been operational since 2002. It comprised a 3-component broadband CMG-1T seismometer buried in the seafloor on "Smooth Ridge," about 40 km offshore in Monterey Bay in 1000 m of water depth. It also included a DPG (differential pressure gauge) and current meter. Since February 2009, it had been linked to the shore through the MARS fiber optic cable so that data were received in real time and available for the earthquake moment tensor (MT) determination system of the Northern California Seismic System (NCSS). Further, the data were archived at the Northern California Earthquake Data Center (NCEDC) at U.C. Berkeley.

As previously reported, in March 2016 monitoring circuitry on MARS began to detect problems with the power feed to MOBB, and it was subsequently powered down on August 3. The cause of the fault was traced to an underwater connector that couldn't be replaced without recovering the whole system. In June 2017, the MOBB data logger electronics and part of the extension cable were recovered. However, due to worsening weather and significant concern for the safety of the crew, the cable had to be cut, leaving ~3,200 m still to be recovered.

After six attempts to recover the cable failed due to bad weather or equipment problems, we finally recovered all of the cable on February 21, 2019. As of November 2020, the buried seismometer remains at the MOBB site along with the empty 2,730-lb. steel, trawl-resistant bottom mount that previously housed the data logger electronics.

Distributed Acoustic Sensing (DAS)

In 2020, Nate Lindsey of the Berkeley Lab once again took advantage of the MARS maintenance period to connect Distributed Acoustic Sensing (DAS) equipment to the dark MARS cable from shore. Pressure waves from sound, earthquakes, tidal flow, etc. effect the way light travels through fiber. This instrumentation can record those effects from the pressure waves and interpret them by injecting light onto the fiber inside the cable and reading the reflections out to about 20 km. Further details are provided here.

Distributed fiber-optic sensing technology coupled to existing subsea cables (dark fiber) allows observation of ocean and solid earth phenomena. We used an optical fiber from the cable supporting MARS during a 4-day maintenance period with a distributed acoustic sensing (DAS) instrument operating onshore, creating a ~10,000-component, 20-kilometer-long seismic array. Recordings of a minor earthquake wave field identified multiple submarine fault zones. Ambient noise was dominated by shoaling ocean surface waves but also contained observations of in situ secondary microseism generation, post–low-tide bores, storm-induced sediment transport, infragravity waves, and breaking internal waves. DAS amplitudes in the microseism band tracked sea-state dynamics

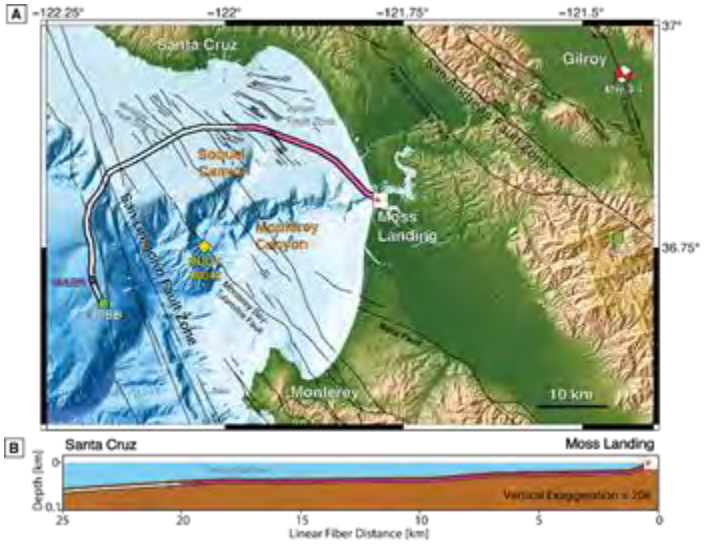
during a storm cycle in the Northern Pacific. These observations highlight this method's potential for marine geophysics.

Since 2018, Dr. Lindsey has deployed his DAS equipment on the MARS cable during the annual maintenance period when the system is dark. The most recent test (August 2020) was a trial of a new piece of equipment that would extend the array to the full length of the cable. Unfortunately, the equipment was damaged during shipping and provided no useful data. A retest will be conducted in October 2020 to validate the new equipment and make a determination as to which DAS sensor will be deployed under the existing National Science Foundation grant.

Plans for 2021

MOBB: The team is evaluating options for reconnecting the seismometer. If an additional hydrophone and accompanying extension cable are deployed for the Naval Postgraduate School at the MOBB site (see the discussion under the "Soundscape Research and Education" project), the team may attempt to reconnect the MOBB seismometer as well.

DAS: Dr. Lindsey plans to continue his work and connect the DAS equipment on shore throughout 2021. In future years, he hopes to develop a marine-deployable version of the DAS.



Cable section illuminated by DAS.

MARS Node Maintenance
Principal Investigator: Craig Dawe, MBARI

(Note: Repair and maintenance of the MARS node and related systems is part of the original MARS project description and is currently approved under Sanctuary permit #MBNMS-2007-030-A8, CCC CDP #E-05-007/consistency certification CC-076-05 and CSLC Lease PRC W 25980/R12903.)

Purpose

The Monterey Accelerated Research System (MARS) has been in virtually continuous operation since October of 2008. In that time, the MARS node electronic package has been functioning reliably, providing scientific data and engineering trials and data, along with operational innovation and experience. The success of this system has enhanced MBARI's reputation as a world-class leader in high-tech ocean science development and has yielded valuable scientific and engineering data to a wide range of programs. While the successes have been great, the systems are showing signs of aging and are very much in need of maintenance.

In 2017, the MARS team planned to perform critical maintenance to the MARS node and components that are beyond end of life. This maintenance has been delayed to begin in Summer 2021 when the primary node will be recovered and work begun on the upgrade/refurbishment. Some of the necessary maintenance/repairs include replacement of the Medium Voltage Converter (MVC, see Figure 1), replacing the aging systems in the Low Voltage (LV) electronics housing, replacement of obsolete Ethernet routers that are at least 12 years old and do not support many new features, problematic science port connectors, and repair of one of the science ports. Such maintenance and repair was anticipated at the beginning of the project, and the system was designed to allow node removal with minimal disturbance to the remainder of the deployed components of MARS. The effort to accomplish this task continues but has been hampered by issues with the main power connector.

Methods/Activities

Once the issues have been solved, the repair/maintenance of the node will continue as follows:

MBARI will construct a “mini” node, which will be put in place to allow the system to continue to operate while the main node is under maintenance/repairs back on shore. The actual schedule will depend on successful build of the “mini” node system onshore. Forty-eight hours prior to deployment, the whole MARS system will be shut down. The “mini” node will be lowered to the ocean floor near MARS. Using an ROV, the team will disconnect the main cable and all the current projects connected to the MARS node (see Figure 2) and release ballast weights from the node to allow the node to return to the surface. The ballast weights will be collected via ROV either at that time or at a later

date, depending on logistics. The "mini" node will then be placed in the node frame, and the cables will be re-connected, subsequent to successful testing of systems.

Maintenance and upgrades to the main MARS node system will take place back in the lab. Once this work has been performed, the main node will be switched out with the "mini" node in a similar manner to the previous "mini" node deployment. Once the main node is installed, standard system verification tests will be run. If all tests go well, the "mini" node and any associated weights will then be recovered from the site. The timing for re-installation of the main node will depend on timing of the initial swap of the "mini" node for the main node.

Activities in 2020/Plans for 2021

In 2019, the National Science Foundation (NSF) received the upgrade plan for the MARS node. This plan was approved and components that could be bought from within the grant have been ordered, such as a new power supply for the node and shore side, replacement wet mate-able connectors, and additional new routers. Plans have been formulated for a recovery. However, as the system is still mostly functional, and there are more users than can be supported by the mini node, the replacement will wait until necessary due to failures, the user requirements are not met by the current system, and/or the number of users drops to a level that is supportable by the mini node.

February 28, 2020 was the end of the current NSF award. A "no cost" extension has been granted and expires February 28, 2021. A new proposal for operation and maintenance of the MARS system has been submitted to NSF. Michael Kelly has been named as the Principal Investigator (PI) for the project.

Cable Monitoring Survey and Report

As reported previously via email, in November 2019, we began collecting data and conducting surveys of the MARS cable in preparation for the next cable monitoring report. The survey was complete in February 2020. After shutdowns and delays in data processing due to the COVID-19 pandemic, the final report was submitted to the regulatory agencies MBNMS, California Coastal Commission, and California State Lands Commission in November 2020.

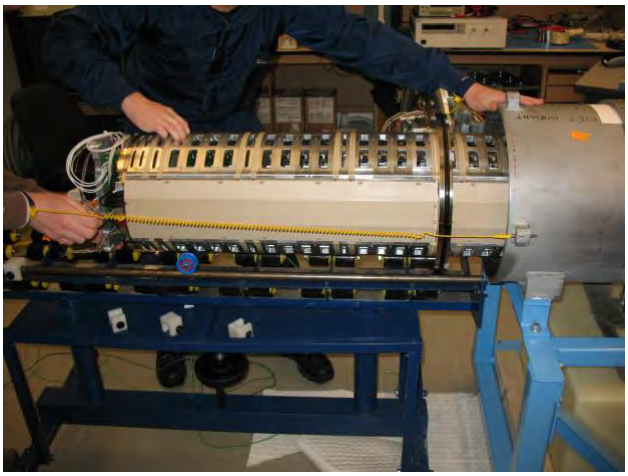


Figure 1. Medium Voltage Converter New MVC from Schaefer Electronics

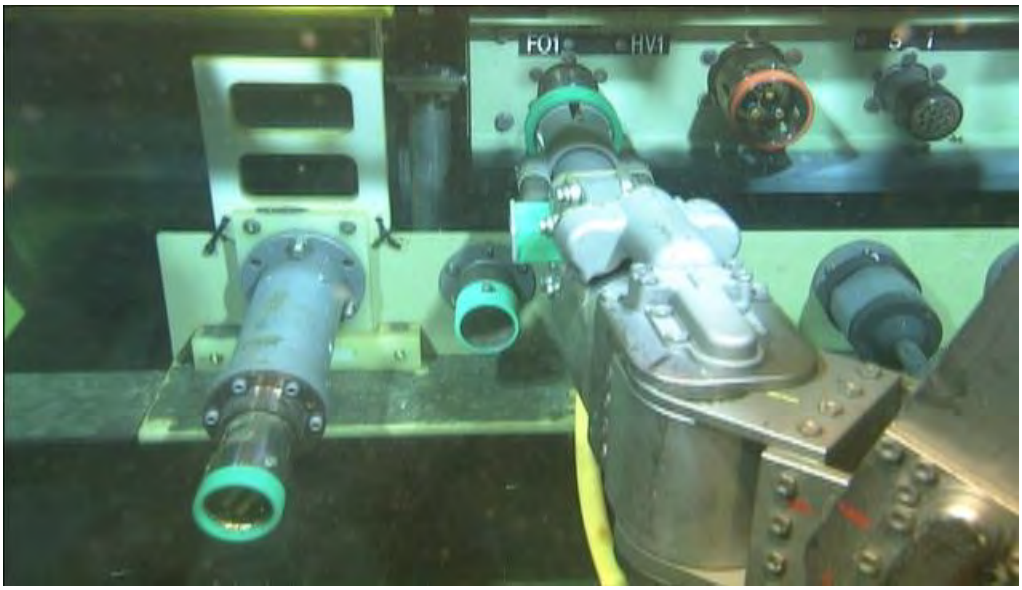


Figure 2. ROV manipulator arm being used to connect a cable to the MARS node.

Geodetic and Seismic Sensor Module (GSSM) Test on MARS
Principal Investigators: Dana Manalang and William Wilcock, University of Washington

Purpose

Geophysical observations on the seafloor in seismically active areas are essential for understanding plate tectonic processes and for assessing and mitigating seismic hazards. Because electromagnetic waves do not penetrate seawater, the GPS receivers that are routinely used on land to measure plate tectonic motions are not an option for geodetic measurements on the seafloor. One method for measuring vertical deformation of the seafloor is to make precise measurements of seafloor pressure. After correcting for tides and other oceanic effects, long-term changes in seafloor pressure can be linked to changes in the elevation of the seafloor.

The challenge of making such measurements is that the sensor typically drifts at rates that are at least ten times the expected rates of uplift or subsidence from plate tectonic motions. The Paroscientific Geodesy Ocean Disaster Sensor (GODS) is a new instrument that seeks to correct for sensor drift by periodically calibrating its pressure sensor against the internal pressure in the instrument pressure housing. Laboratory tests of this method, termed A-O-A, are promising, but it needs to be evaluated on the seafloor. The GODS sensor also includes a new type of accelerometer that is designed to monitor for earthquakes.

Objectives

The objectives of this project are to test a new geophysical sensor, the Paroscientific GODS sensor, on the MARS cabled observatory for at least one year. The sensor provides continuous time series data for: (1) seafloor pressure calibrated to remove sensor drift, and (2) the acceleration of the seafloor.

Activities in 2019/2020

The system was deployed on 06/13/2017, and remained deployed throughout 2018 and most of 2019. It was recovered on December 17, 2019. The testing demonstrated the calibration techniques to be valid, and the results to date are very encouraging, suggesting that the A-O-A method will provide a new geodetic tool for measuring long-term motions of the seafloor in tectonically active regions with an accuracy of a few millimeters. In regions where the seafloor is stable, the sensor may provide a means to measure long-term changes in sea level. The system was not deployed on MARS in 2020 but will be deployed later on an active cabled observatory.

Plans for 2021

There are no current plans to re-deploy in 2021, but it may be deployed again in the future.

Figure 1. *Prototype of the GODS (Geodesy Ocean Disaster Sensor), which is inside the GSSM housing. For cabled deployments, this is combined with an actuator to turn the valve and electronics to acquire data and interface to the cable.*

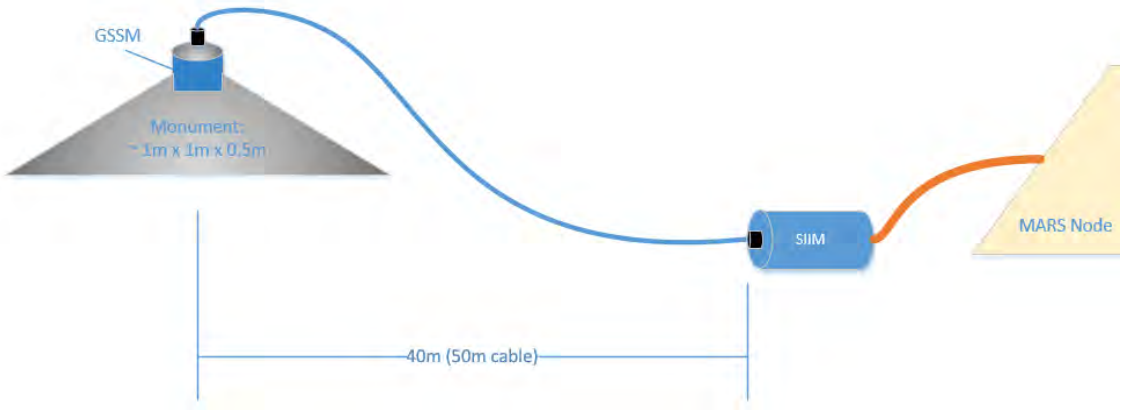


Figure 2. *Schematic of the deployed system.*

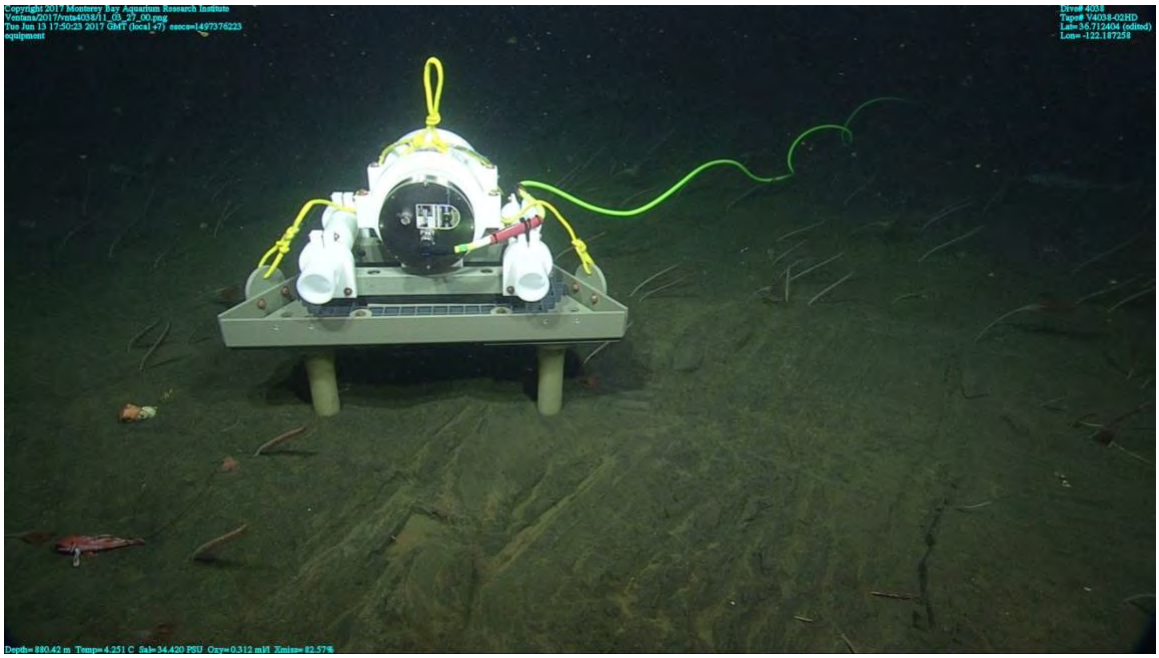


Figure 3. *The GSSM system as deployed on MARS.*

The Quest Institute Ocean Discovery Program
Principal Investigator: Danny Kim, Stephen Huber (both from Quest), Craig Dawe, MBARI

Purpose

The Quest Institute (QUEST) is partnering with Monterey Bay Aquarium Research Institute (MBARI) in utilizing the Monterey Accelerated Research System (MARS), a phenomenal STEM education learning environment. QUEST has experience developing STEM education programs through innovative platforms. QUEST's Quest for Space (www.questforspace.com) is a STEM student experiment platform on the International Space Station. The ISS program is not only a technical platform, but also a supportive infrastructure for teaching, learning, and skill development in science and engineering. To support participating organizations, Quest for Space provides hardware, software, lesson plans, experiment booklets, discussion forums, help desk, and more.

QUEST is developing the Ocean Discovery Program using Quest for Space as a blueprint. The Ocean Discovery Program (ODP) will include education support material, online community groups, etc. ODP's mission is for "STEM Education through Ocean Exploration" to be available as a project-based learning opportunity. For an all-encompassing STEM program, physical science experiments combine with engineering design in hardware and programming of software for automation. ODP structure allows for small teams of scientists, engineers, and programmers to work together in scientific investigation. In the beginning of the program design and development, QUEST will utilize local students as MBARI is within driving distance. MBARI engineers are engaged as mentors and will be utilized to best define how to grow the program.

Because MBARI already has acoustic data from MARS, citizen science is ready to be deployed in the ODP. As development builds, students will design and develop additional hardware and software for audio, video, and seawater composition evaluation.

Education Impact

The Earth is over 70% water. Yet, the average students know very little about our planet's waters. We know more about space than we do the ocean. The Ocean Discovery Program educational support material anticipates four Units: Introduction, Sounds of the Ocean, Sights of the Ocean, and Chemistry of the Ocean. Quest has invested heavily in an online learning platform that focuses on the Monterey Bay in general with the opportunity to utilize the Quest Ocean Discovery platform hardware as a reward for the completion of lessons.

Methods/Procedures

Ocean Discovery intends to conduct experiments in the areas of chemistry/biology, video, and acoustics. There is also a plan to deploy an ROV equipped with a camera. All planned activities will be deployed on the same benthos glass sphere platform (see Figure 1).

Chemistry/biology: The goal of this experiment is to grow bacteria/algae on a surface using a light and analyze the bacteria to determine species. Our plan is to analyze at depth using a stereo microscope that can be remotely focused. We will encourage the growth of bacteria on the outside of a clear lens by shining a bright light on the lens' surface. The bacteria/algae are naturally found in the environment and no chemicals or medium will be introduced or used. The motivation for this experiment was due to an earlier experiment conducted by MBARI where there was a camera and light mounted on top of the MARS node. The light was continuously illuminating the cover of the node and when MBARI retrieved the camera with an ROV, they were surprised to find that bacteria/algae had grown on the cover. MBARI has not had the opportunity to identify the bacteria and our students decided to take on the challenge.

Quest is also considering including a CTD and a salinity sensor as well on their 2021 platform to observe if there is a change over time or between seasons.

Ocean Current & Direction: During its 2019 deployment, the Quest team was surprised to see such a wide variation in ocean current. For their 2021 platform, Quest is seeking to include a sensor to be able to track and log the ocean current strength and direction.

Geological: Quest will include a "Raspberry Shake" to measure and log seismic activity. This low-cost yet effective sensor will provide another educational opportunity on the platform.

Video: The goal of this experiment is to inspire students with the sights of the ocean using a 3D camera. The camera will have the capability to be remotely controlled. Quest is researching upgrading this system in its 2021 deployment to be externally mounted to a pan and tilt system instead of within the glass sphere.

Acoustics: The goal of this experiment is to teach students how to identify underwater sounds. We will accomplish this using a passive hydrophone.

ROV: The goal of this experiment is for the students to learn, and put into practice, the engineering disciplines and skills necessary to design a deep water ROV and pressure vessels required to withstand 900 meters. Additionally, this hands-on and interactive experiment will be used to engage the interest of new participants of schools everywhere in marine engineering and science. For 2021, Quest is planning to add further video capabilities to the ROV platform (see Figure 2).

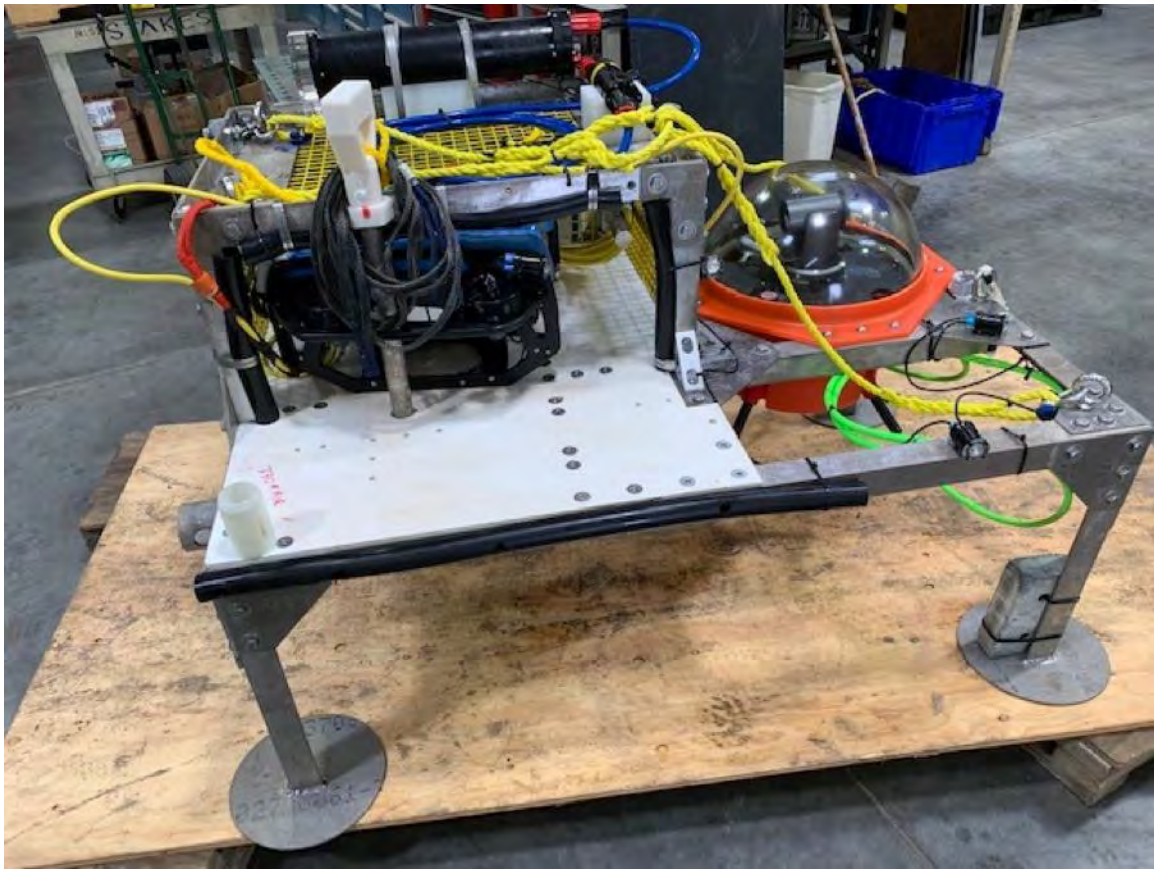


Figure 1. Quest Ocean Discovery 2019 Platform.

Figure 2. An example of the ROV that was deployed on the system.

Intended Use of Results

Results will be used solely for the purposes of scientific research and education. The results of the experiments will be available to all partners and participants in the Ocean Discovery Program. The Quest Institute is a non-profit organization that generates revenue by developing excellent STEM programs that are offered to schools at prices that any school can afford. We anticipate developing Ocean Discovery into a full science curriculum.

Results to Date

Several videos and pictures were taking from the Ocean Discovery platform while it operated from May through October 2019. Students through Quest and researchers at MBARI were surprised to see how much life was observed around and near the Quest platform. The ROV successfully demonstrated that a miniature low-cost ROV could be permanently deployed for long durations.

Activities in 2019/2020

The Ocean Discovery Platform was redeployed in 2019. The system remained functional until October 19, 2019 when a ground fault was detected. The source of the ground fault has yet to be determined, and the platform was recovered in December 2019. Despite the eventual failure, the platform was an amazing success in that students were able to engage with the ocean like never before. The concept has now been tested and confirmed that the demand and interest from students is overwhelming. Due to the COVID-19 pandemic, plans for 2020 were deferred.

Plans for 2021

The Ocean Discovery Program platform will be re-deployed 2021 with updated hardware that seeks to improve reliability and longevity in addition to adding some additional capabilities and activities for students to utilize. The additional experiments/capabilities will include a seismic sensor, ocean current sensor, CTD sensor, and improved camera capabilities. The overall shape and size of the Ocean Discovery platform will remain mostly unchanged.

Monitoring Pelagic Biomass Fluxes in Monterey Bay
Principal Investigators: Kelly Benoit-Bird and Sam Urmy, MBARI

(Please note: This project was previously approved and deployed in 2009-2010 under Sanctuary permit #MBNMS-2007-030 and CCC CDP #E-05-007/ consistency certification CC-076-05. The Principal Investigator at the time was John Horne, University of Washington. Sam Urmy worked on the project at the time and will be collecting data to compare to results of the previous experiment.)

Purpose

Distributions of mobile aquatic organisms vary in time and space. A fixed acoustic sensor mounted in conjunction with continuous power supply and data relay capability facilitates an examination of the flux and scale-dependent temporal variance of fish and zooplankton. Monitoring the distributions and movements of cetaceans, fish, and zooplankton would greatly improve the biological and ecological understanding of many species. The basic question is, "What are the movements and predation of nekton within the monitored volume and their relationship to environmental conditions during those movements?" This question addresses biological processes of migration, predation, and interaction with the environment. Using video surveys and environmental DNA to identify constituents, we have been developing species-specific census counts for population monitoring and stock assessment of commercially important resources. Setting the acoustic sensor in a sanctuary reduces anthropogenic impacts on animal distributions and movements.

Objectives

Objectives for this monitoring project include:

- quantifying distributions and fluxes of marine organisms relative to environmental conditions
- understanding the intensity of biological responses to episodic physical events
- estimating pelagic nekton biomass as a function of season
- comparing patterns in animal distributions to those obtained a decade ago to examine the responses of the system to environmental change
- examining the relationship between predators detected with the hydrophone at MARS and their food resources measured by the echosounder

Methods

The acoustic platform was deployed on January 29, 2019 at a position of 36.712110, -122.187028 connected to the MARS observatory. Deployment was done using MBARI's ROV *Ventana* and will eventually be retrieved the same way.

EK60

The Simrad EK60 38 kHz echosounder is an active acoustic source similar to a depth sounder or fish finder. The energy from the transducer is concentrated in a 7^{o} circular beam (half power points) from the transducer face. At a range of 950 m, the diameter of

the acoustic beam is 116 m. The source level of the transducer is less than 180 dB re 1 μPa at 1 m, below the guidance issues by the National Marine Fisheries Service for preventing temporary hearing impairment for marine mammals (National Marine Fisheries Service 2003). At a range of 100 m this sound pressure level is reduced to below 140 dB re 1 μPa assuming ocean water (10^{o} C and 32 ppt). Each pulse has a duration of 0.512 ms and the duty cycle of the echosounder is one pulse every 2.5 seconds.

2020 Activities

The echosounder has been active nearly continuously since its deployment early in 2019. During two, 2-week-long periods, extensive observations of animals and their environment. These experiments also included measurements near MARS with i2MAP (Dorado class AUV), *Ventana* (ROV), and LRAUVs. Our goals were to integrate acoustics with video imaging and environmental DNA. The results have revealed that vertical migration is much more variable from day to day than previously believed, with the potential for large effects on carbon sequestration by the ocean.

During 2020, we also began conducting surveys using a Wave Glider also carrying an echosounder to connect MARS, the midwater time series site, and the mooring site at M1. Our goal is to scale up the measurements from MARS to the rest of the midwater of Monterey Bay and provide the opportunity to integrate other available data sets including nearly 30 years of video transects and decades of environmental measurements.

DEIMOS has also become a testbed for the integration of acoustics with other tools including eDNA, passive acoustics, and video imaging. LRAUVs with video capability were deployed to test video capabilities within layers identified by the echo sounder. Using a Wave Glider as a navigational gateway, the LRAUVs were able to maintain position inside the beam of the echo sounder and are providing a new tool for the identification of biology in the bay and helping us further the goal of autonomous stock assessment for important living marine resources. The project has also been supporting Ken Smith's deep sea export measurements at MARS, allowing us to directly explore the relationship between vertical migration and export.

Intended Use of Results

Results of the study will be used in further research, published in the scientific literature, and have already been presented at several scientific conferences. Two manuscripts are currently in review. In addition, the echosounder is being used as a test platform for the development of new, autonomous stock assessment tools.

Plans for 2021

The echosounder will remain deployed through 2021 using the same sampling parameters. These data are providing an important opportunity to examine the ecology of Monterey Bay in the context of a changing planet. As the time series grows in length, the power of these data to resolve changes in response to changing levels of oxygen and increased temperatures is great. In 2022, the team is planning to deploy an upgraded system. Details for that system will be included in the next annual report.

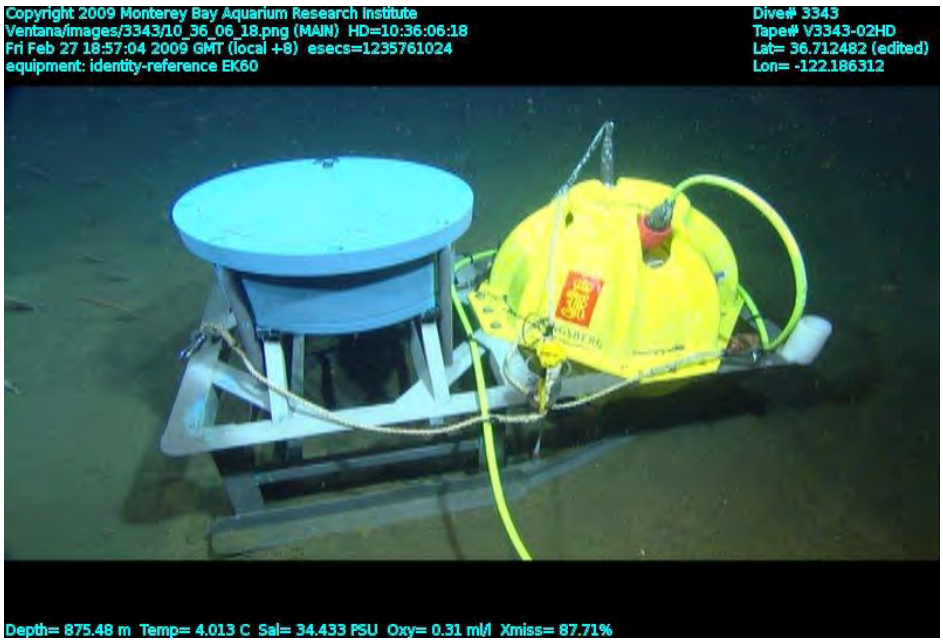


Figure 1. *The EK60 echosounder deployed on MARS in 2009-2010. The same system is currently deployed and will remain in place for 2021.*

References

National Marine Fisheries Service (2003) Taking marine mammals incidental to conducting oil and gas exploration activities in the Gulf of Mexico. Federal Register 68: 9991–9996

DeepSea Connect
Principal Investigator: Craig Dawe, MBARI

(Note: This project was originally included as part of the approved Quest Foundation projects to be jointly developed by MBARI and Quest. MBARI took over development of this system, so it has been included separately in the report. Note that Quest has plans to incorporate the Raspberry Shake seismometer in their platform in 2021.)

Purpose

The goal of DeepSea Connect is to provide a low-cost, wireless connection from MARS to low-power, low-bandwidth science experiments, reducing the need for expensive subsea connectors and making connection easier. It is focused on STEM projects where funding and power requirements are usually limited. The Raspberry Shake seismometer is to be used a proof of concept for the project (described below).

Expanding MBARI's educational mission with the Aquarium and other educational out-reach programs can be greatly enhanced by taking advantage of one of our most unique assets (MARS). This project will significantly reduce the cost and complexity for educational programs to stream live data to the classroom.

The project has interest from the Aquarium, the Quest Institute (STEM platform for students around the world), and the MATE program.

Methods

DeepSea Connect will provide a low-cost, wireless connection from MARS to low-power, low-bandwidth science experiments. The project plans to take COTS (Commercial Off-The-Shelf) hardware and adapt that technology to work in the required environment.

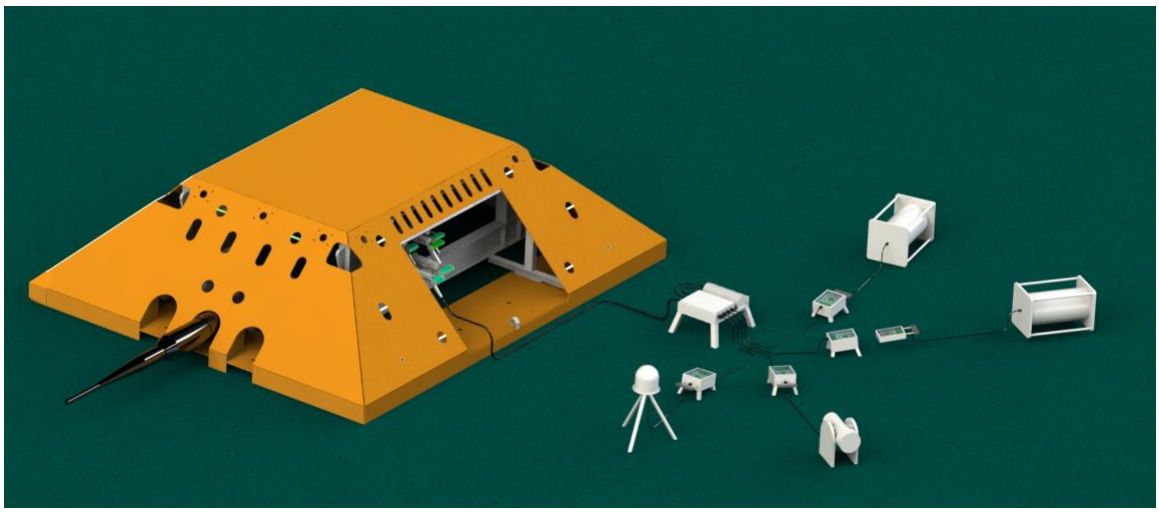


Figure 1. Conceptual drawing of DeepSea Connect system.

DeepSea Connect will be an open source interface design. We will manufacture and set the interface blocks for end users and test nodes. A test node will also be developed and connected to the MARS wet node simulator on shore.

As mentioned above, the Raspberry Shake seismometer is a piece of equipment that will be deployed as a proof of concept of the DeepSea Connect system. The Raspberry Shake is a low-cost seismometer based on professional grade instruments. It will provide real time data from one of the few sensing devices installed in the deep ocean. It will be connected to the internet where a network of these devices and the data can be viewed and analyzed by the public and research concerns. Please see https://raspberryshake.org/about/technology/ for further details.

Figure 2. Raspberry Shake seismometer.

Activities in 2019/2020

The system was deployed on December 17, 2019. Upon connection to MARS, data began streaming to: https://raspberryshake.net/stationview/#?net=AM&sta=R5E0E, where the location and data plots were available live to the public, along with other seismometers on the network. This deployment, with sensor placed and connected in the deep ocean, was a first for the Raspberry Shake network. Some technical issues required the device to be recovered in April 2020.

Plans for 2021

The system will not likely be ready for re-deployment in 2021. However, planning is in the process to re-deploy in 2022 after the MARS node is upgraded. Enhancements would include an increase in power transfer and a method to secure the transmitter and receiver pads to avoid being disturbed by ocean currents, etc.

Monterey Bay Aquarium Whalefalls High Definition Video Feed for Live Stream and for Time-Lapse Purposes
Principal Investigators: George Matsumoto, MBARI, John O'Sullivan, Monterey Bay Aquarium (MBA), and Shana Goffredi Occidental College

[Note that the original plan and authorization provided in 2019 was to install camera tracks and cameras near whalefalls at the MARS node (described below). The team is still developing plans for the best solution to capturing video and/or images, and may only utilize free-standing, battery powered camera systems, particularly in the first few years of the exhibit. As mentioned in last year's report, the team is also expanding the area to deploy whale carcasses from one km up to three km away from the MARS node. Please let us know if you have any questions or if any additional action is needed for that change.]

Purpose

The Aquarium will be opening a new Deep Sea Exhibition in 2022. The goals of this multi-year (8+ years running) exhibition is to share the unique animals, threats, research, education, and conservation topics associated with this environment. One of our methods to reach our audience is to potentially provide a live video feed that can be streamed over the web to external and internal audiences. Of the numerous planned new live animal exhibits displaying deep- and open-water species, we have chosen a whalefall exhibit theme for a potential video feed during our open hours. (Note that the live video feed will not happen in the first year or two of the exhibit but may happen at some later point.)

Our field operation plan is to sink a number of naturally occurring whale carcasses over the duration of our exhibit within three kilometers of the MARS node. (This activity is currently permitted by the Sanctuary under permit #MBNMS-2018-013, but was previously planned for up to one kilometer from the node. Please let us know if any adjustments are needed in the permit to increase the potential sinking location.)
Over the duration of the whale fall, MBA would document the whale fall ecosystem using MBARI's remotely operated vehicles and perhaps some stationary battery-powered cameras. At some point in the future, this may be followed by the deployment of 1–3 camera systems (either plugged into MARS or not) consisting of cameras, lights, and/or a rail track (exact specifications are still to be finalized) to provide a live video feed through MARS to the Aquarium. Our camera systems (on a track and plugged into MARS and/or not plugged into MARS) may be deployed separately, or at the same time, to accommodate multiple whalefalls and different aspects of our visual exhibit requirements such as live feed, zoom and tilt, wide angle, time-lapse, and still images. Camera systems may be for short- and/or long-term deployments, at a fixed location, or possibly on an approximately five-meter-long track to provide different imaging of the whalefall and associated species. All systems are being designed for long-term deployment, to be serviced and recovered. MBARI ship and ROV time has been approved specifically in support of this field program. The sinking of the whale carcass(es) will be accomplished using the R/V *Shana Rae* and primarily MBA staff.

Objectives/Methods/Procedures

This project has multiple objectives over the eight-year operation to support the live video feed from the whalefall(s) at MARS.

1. Our first objective is to conduct a test sinking of a whale carcass to ensure we have all of the equipment that is required and can place (sink) the whale carcass within approximately 700 meters of a specific location.
2. We will visit this whale fall as often as possible using MBARI's remotely operated vehicles and using days already allocated to MBA in 2021.
3. We may deploy an independent (unattached to MARS), battery-powered camera system to capture the initial larger predators that are attracted to a fresh whalefall during the first several weeks of deployment.
4. Over the duration of this project, collections for our exhibits and research will be designed to take advantage of each whalefall in this program.
5. Over time, additional whales will be sunk as opportunity provides. Location for these additional whales will depend on things such as weather conditions and live video plans. (If live video goes forward, we will want to place the whale close to MARS).

Intended Use of Results

Based on our present exhibit design plans, the Aquarium intends to interpret to the public the new genus (*Osedax*) and 14+ new species of worms found (by MBARI) that colonize these bones, in addition to other deep-sea species that can be found inhabiting a whalefall. Our primary outcome would allow the introduction of nearly 2 million visitors a year to the variety and complexity of this and other deep-sea ecosystems, and the new discoveries being made about life and the ecosystem processes in this poorly-understood environment.

Our Education, Conservation, Research, and Policy teams will use these deep-sea exhibits as a vehicle to address ocean conservation topics (including ocean acidification and plastic pollution—whalefalls may act as a barrier fence and catch plastics drifting in the deep sea) and policy topics that support the need to continue deep sea research and to protect deep habitats. Presently no commercial use has been identified.

Researchers include Dr. Shana Goffredi (Associate Professor, Occidental College and MBARI Adjunct Scientist) and Dr. Luciana Genio (Universidade de Aveiro). Dr. Goffredi's research is described below. Dr. Genio is proposing an ancillary project to investigate larval recruitment around whale falls and is working with MBARI's Dr. Ken Smith on a larval suction sampler system to be placed near the whale fall.

Outreach: In addition to the 2,000,000 annual guests visiting the Aquarium to see this exhibition first hand, our social media outreach includes 3,583,000 followers as well as another 3,000,000 on the web. MBARI social media outreach adds to that total.

Collections
While the MARS deployment would basically involve camera systems and tracks to support video documentation of activities at the whalefall site(s), there are a number of related activities in conjunction with the video component that are authorized under other permits.

Bone material from the whale falls will be collected using the ROV to support exhibits at the Aquarium, including a bone worm exhibit (currently authorized by the National Marine Fisheries Service). In addition, various deep-sea invertebrates may also be collected, depending on recruitment. Organisms collected for display will be collected under California Department of Fish and Wildlife (CDFW) Scientific Collecting Permit (SCP) #2026 and their CDFW General Use Permit ID: GM-190810004-19081-001 issued to the Aquarium.

Research collection sampling for Dr. Goffredi will attempt to quantify the activity of microbes, both free-living and symbiotic, at whalefalls using *in situ* ecological experiments, combined with molecular, microscopic, isotopic, and geochemical analyses. The vast majority of research to date on microbes living in sediments, on hard substrates, and in association with animals has been based on inference from static 'snap shots' of samples collected from a single point in time. As such, we know very little about the temporal dynamics of metabolic activity, response time, and patterns of succession by microorganisms in response to localized, and heterogeneous, nutrient availability and other physical/chemical conditions. Here we hope to collect seafloor sediment and animals, as well as conduct experiments, including *in situ* colonization and incubation experiments near the area of whalefall biomass influence. Additionally, we hope to attract *Osedax* polychaetes and their bacterial symbionts. This novel group of worms act as ecosystem engineers and acquire their symbionts new each generation from the environment, thus a spatial and temporal view of symbiont variability, both within animal tissues and free-living, is an important goal. Whalefalls (or other large inputs of organic carbon) are hotspots for nutrient cycling in the deep sea. With MBARI technology, these environments can serve as unique natural laboratories in which to investigate the microbial metabolic interactions underpinning carbon, sulfur, and nitrogen respiration. These activities are authorized under MBARI's permit with the Sanctuary (MBNMS-2020-006) and the Aquarium's MBNMS Permit # 2018-013. Additionally, Dr. Goffredi is authorized for collections for her work under CDFW SCP #SC-10578.

Plans for 2021
11/2020–10/2021: Conducting a test sinking of a naturally occurring whale carcass to ensure we have all of the equipment that is required on site and can place (sink) the whale within approximately 700 meters of a designated location. This whale will also be used for collection of specimens for exhibit and/or research. Possibly deploy an independent (unattached to MARS), battery-powered camera system to capture the initial larger predators that are attracted to a fresh whale fall during the first several weeks of deployment.

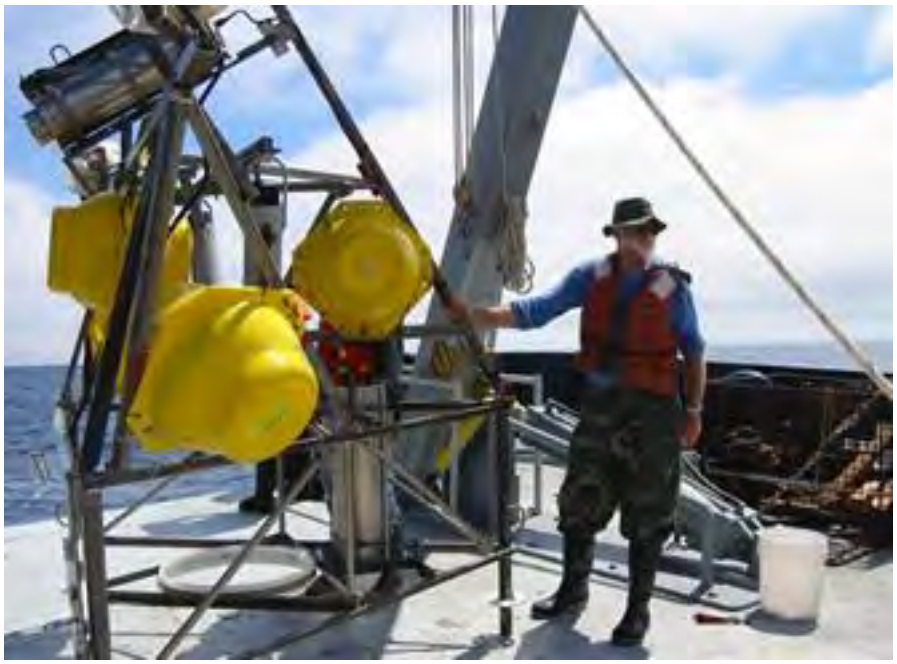


Image of the MBARI time-lapse camera system deployed by Dr. Ken Smith at Station M (4000 meters). A similar structure could be deployed at MARS.

System Specifications: Proposed whalefall camera track overview and diagram (if needed)

Schematic of a potential design for a camera rail system.

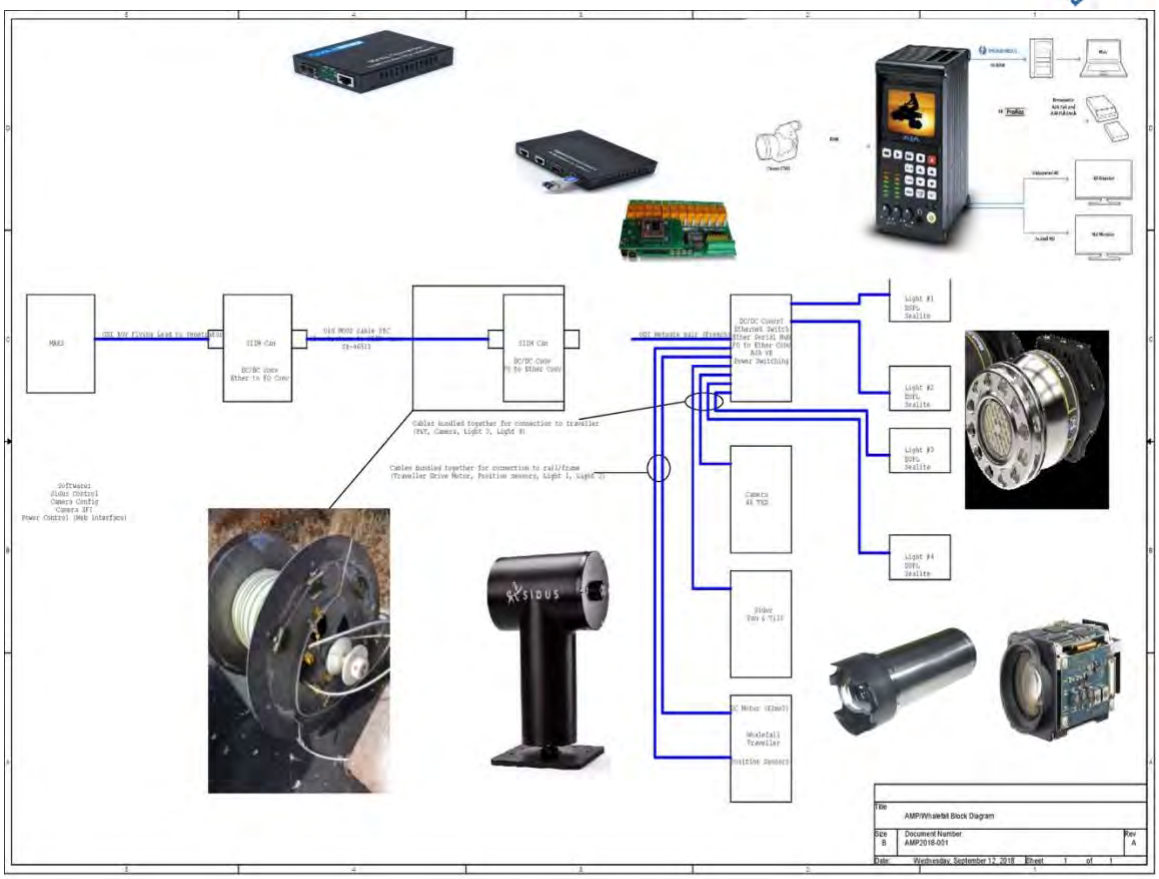
Components

Beam Assembly

- Beam (3-5 meters)
- Linear Rail (IGUS 1660)
- Linear Traveler (IGUS 1660 RHA)
- Compensated Motor Housing & Compensator
- MAXON motor & Controller
- Connector (plug) Panel
- Cable Management (IGUS E2 ChainFlex)
- Capstan & Support bearings
- End Sheaves & Bearing Mounts
- Ballast
- Flotation
- Pick Point

Weights (in air)

- Steel Beam assembly 600 pounds...total assembly< 1,000 pounds
- Aluminum Beam assembly 300 pounds…total assembly< 700 pounds
- Composite Beam assembly 300 pounds… total weight < 700 pounds
- Ballast & Flotation +600 pounds
- Camera 11.25 lbs
- P&T 9.3 lbs
- Lights 2 lbs
- Cables 85 lbs
- Possibly Tiburon power can



Proposed camera video schematics.

Sedimentation Sensor/Time Lapse Camera System
Principal Investigator: Ken Smith

Purpose

The Sedimentation Event Sensor (SES) is a sediment trap mounted on a rotating plate, allowing the collected sediment to be imaged for composition and size, and measured for chlorophyll content.

Deployment on MARS allows the team to make in-situ adjustments of camera exposures and light levels. The knowledge gained from the MARS deployment will be used to set up the instrument for autonomous, stand-alone sampling at Station M, a remote site outside of the Sanctuary, where it will remain for 12 months. The SES will supplement the conventional sediment traps and other instruments deployed there.

Activities in 2020

The system was deployed on MARS on August 18, 2020. The deployment identified a clogging problem with the instrument, and it was recovered in September. The clogging was due to an excess of sediment particles at MARS, but the instrument worked well electronically. The SES was then deployed at Station M in October for a full year deployment.

Plans for 2021

There are no current plans to deploy the system again at MARS. However, if the team needs to conduct any additional engineer testing, it may be deployed again at some point in the future.

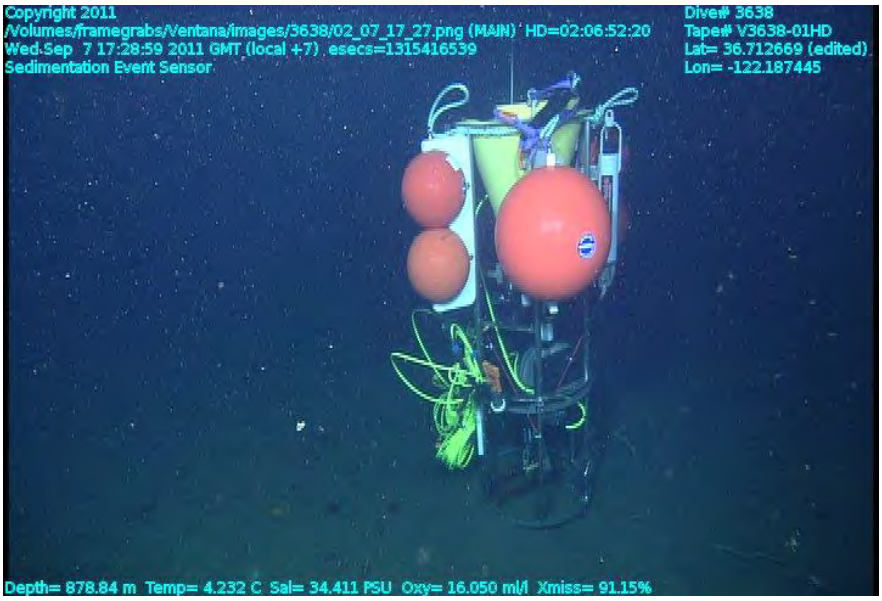


Figure 1. This image shows the Sediment Event Sensor (SES) on the MARS observatory in Monterey Bay.

Other Approved Projects to be Potentially Deployed in Future Years

MARS Camera—Photographic Benthic Observing System (PhoBOS)/Serenity Light
This system was last recovered in December 2018. There are no current plans to deploy the camera, but it is possible a deployment plan may be developed in future years.

Development of Chemical Sensors and In-Situ Calibration: Enhanced Monitoring and Measurement of pH and Redox in Diffuse Flow Hydrothermal Systems
The project team received funding for a future deployment that was originally planned for the end of 2015. However, this deployment has been delayed again. A 2021 deployment could occur, but it is more likely to happen in a future year.

Methane Hydrates and Microbial Growth
This project may still be deployed on MARS at some point, but there are not currently any specific plans for deployment.

Deep Environmental Sample Processor (D-ESP)
The last deployment of the D-ESP on MARS occurred in 2013. There are currently no plans to deploy the system on MARS in 2021, but future deployments may be planned.

Free Ocean CO2 Enrichment Experiment (FOCE)
This system was last deployed on MARS in 2011, and there are no current plans for redeployment. However, there are tentative plans for a modified respiration system to potentially be proposed using FOCE technology at some point in the future.

Sensors powered by benthic microbial fuel cells at the MARS Observatory
This system was last deployed on MARS in 2011-2012. As previously reported, it was only partially successful and the system needs further development. There are not currently any plans for redeployment on MARS, but it may be deployed again at some point in the future pending funding.

Eye-In-The-Sea (EITS)
This system was last deployed on MARS in 2009-2010. While there are no current plans for deployment in 2021, the project team may wish to deploy the system in the future.

Benthic Rover
This equipment was last deployed on MARS in 2009 for several engineering tests. Since that time, it has been deployed autonomously at Station M, a site over 4000 m deep located 220 km west of the central California coast, and well outside the MBNMS. There are currently no deployments scheduled for the Rover on MARS. However, if any additional testing of equipment or software is needed, MARS is the best method for completing these tasks.

A Smart Sensor Web for Ocean Observation

The deployment of this system on MARS remains uncertain. However it is included in this report update in the event that the project receives additional funding and plans to deploy. It is currently approved under Sanctuary permit #MBNMS-2007-030-A8 and MBNMS-2002-039-A1 (vertical profiler mooring), CCC CDP #E-05-007/consistency certification CC-076-05 and CSLC Lease PRC W 25980/R12903.

Project name	PI	Summary of activity	Date of experiment	Location (lat/lon)	MBNMS prohibition	Action (~# of cores, equip left behind, etc.)	Equipment used	Assessment of impact
Geodetic and Seismic Sensor Module (GSSM) Test	Dana Manalang/ William Wilcock	Deployed GSSM system	Deployed 6/13/17 Recovered December 17, 2019	36.712404 N 122.187258 W	Seabed disturbance	Deployed GSSM system	ROV Ventana, GSSM	Minor seafloor disturbance. Conditions will return to normal shortly after recovery.
Monterey Ocean Bottom Seismometer (MOBB)	Romanowicz et al.	MOBB seismometer remains deployed along with trawl-resistant frame, but it has been disconnected from MARS until connectors can be repaired and new cable/connectors can be re-deployed.	Originally ongoing. 8/3/16: System powered down. 6/2017: Datalogger and part of extension cable recovered. 2018: Several attempts were made to recover the remaining cable in April and July. Will attempt again in December 2018. 2/21/19: Recovered remaining cable. Plans to re-deploy cable and reconnect if funding is available.	36.69064 N 122.16603 W	Seabed disturbance	MOBB seismometer remains buried and deployed, along with trawl resistant frame. Data logger elecronics and extension cable recovered.	MOBB seismometer system	Minor disturbance to seafloor.
Subproject of MOBB: Distributed Acoustic Sensing (DAS)	Nate Lindsey	From shore, send light through cable to measure changes via pressure waves.	2018-present during MARS maintenance periods	On shore	N/A	Light emitted through cable from MARS shoreside lab.	Distributed Acoustic Sensing (DAS) equipment	No impact as all activities were enclosed in cable and done from shore.
Soundscape Research and Education (formerly Passive Acoustic Sensing in Foraging Ecology Research)	John Ryan	Deployed passive acoustic monitoring (PAM) system	Deployed 7/28/15 Recovered and re-deployed 6/23/17. Directional hydrophone deployed in February 2019. Both hydrophones are planned to remain deployed throughout 2021.	36.712736 N 122.186032 W	Seabed disturbance	Deployed passive acoustic monitoring system	ROV Ventana, hydrophone	Minor seafloor disturbance. Conditions will return to normal shortly after recovery.
Quest Institute Ocean Discovery Program	Danny Kim, Stephen Huber (Quest), Craig Dawe (MBARI)	Deployed Ocean Discovery Program platform.	Deployed/recovered October 2018. Re-deployed May 2019. Ground fault October 19, 2019. Recovered December 29, 2019.	Approx. 36.712404 N 122.187258 W	Seabed disturbance	Deployed Ocean Discovery Program platform, which includes a small ROV, pan and tilt camera system, microscope to study algae growth, and a hydrophone.	ROV Ventana, Ocean Discovery Program platform	Minor seafloor disturbance. Conditions will return to normal shortly after recovery.
Monitoring Pelagic Biomass Fluxes in Monterey Bay	Kelly Benoit-Bird, Sam Urmy	Deployed EK60 system	Deployed 1/29/19. Plans to leave it deployed on MARS throughout 2021.	36.712110 N 122.187028 W	Seabed disturbance	Deployed EK60 system	ROV Ventana, EK60 echosounder	Minor seafloor disturbance. Conditions will return to normal shortly after recovery.
DeepSea Connect	Craig Dawe	Deployed DeepSea Connect system with Raspberry Shake seismometer	Deployed December 17, 2019 Recovered April 14, 2020	36.712370 N 122.186481 W	Seabed disturbance	Deployed DeepSea Connect system with Raspberry Shake seismometer	ROV Ventana, DeepSea Connect system with Raspberry Shake seismometer	Minor seafloor disturbance. Conditions will return to normal shortly after recovery.