Project Summary

Funds are requested for the continuation of the ALOHA Cabled Observatory (ACO) project providing infrastructure in support of real-time science at Station ALOHA, the site of more than 20 years of deep water oceanographic investigations 100 km north of Oahu, Hawaii. The ACO uses a retired commercial telecommunications cable donated by AT&T to provide an "extension cord" from shore to Station ALOHA. The observatory node contains eight ports that investigators can plug into on the ocean floor, using an ROV, to obtain continuous electrical power and an Internet connection between their instruments, their desk on shore, and anywhere else on the Internet.

The first phase of installation was completed in February 2007, which included cutting, moving, and terminating the end of the cable at Station ALOHA. An experiment package was connected directly to the cable and has proved the design concepts by transmitting 20 months of nearly continuous pressure and acoustic data to shore in real time. An attempt to install the Phase-2 node of the ACO in October 2008 was thwarted by the failure of commercial underwater optical connectors within the observatory.

In this next phase, we will complete the installation of the ACO and begin operations. We will make changes to the observatory system to lessen the dependence on optical connectors. Basic science instrumentation that will uniquely address abyssal science questions will also be installed, including acoustic Doppler current profilers, conductivity, temperature and depth sensors, an acoustic modem, a 200-m-tall bottom-moored thermistor array, hydrophones, an absolute pressure sensor, bio-optical sensors, and a video camera. The installation will require the use of a dynamically positioned research vessel and the ROV *Jason*. Phase-1 data and new Phase-2 data will be archived and made available to the public via an Internet database and web interface.

Intellectual Merit

The ability to control experiment operations in real-time and access hundreds of watts of power continuously provides options to experimenters that are not possible without an observatory cabled to shore. Initial instruments will address diverse science topics, including over-sill flow and stirring between deep ocean basins, variability and trends in deep salinity, shallow-to-deep sea carbon export events, marine mammal distributions, and surface wave-wave interactions. An acoustic modem will communicate with a nearby subsurface mooring with water-column profiler. The installation of the ACO node enables a distributed abyssal observatory network, including cable-powered, full-water-column mooring systems supporting capable profilers with sophisticated sensors, as well as mobile vehicles (with docking) and remote autonomous nodes.

Broader Impacts

The ACO builds on decades of previous experience and is the only abyssal (~5,000 m) ocean observatory, current or planned, in the world. The ACO will expand the scope and footprint of the NSF Ocean Observatories Initiative (OOI), building on the existing world-class Hawaii Ocean Time-series, while providing a model for future extensions of the OOI. Facilities such as these will provide new and different opportunities for educating students and the public, far beyond the resources and tools accessible by undergraduate and graduate students currently participating on this grant.

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Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Introduction

We request renewal funding to complete the installation of the ALOHA Cabled Observatory (ACO) and begin operations. Failed underwater optical connectors thwarted what otherwise would have been a successful final installation in October 2008. We are working closely with Ocean Design, Inc., the connector manufacturer, to resolve the problems that were found and to conduct extensive testing. To further mitigate risk of connector failure, one of the system modules will be slightly modified and reconfigured to isolate the single remaining optical connector. For purposes of planning this two-year effort, we assume that installation using the required UNOLS ship and ROV *Jason* will occur at the start of year 2 (July 2010), with research and operations continuing through the second year.

Operations will include monitoring the engineering stability of the system and managing the data, as well as developing relevant management procedures and practices, and generating the community interest needed to sustain the observatory. Data will be made publicly available via an Internet web site. Individuals supported on this grant will analyze the data from the initial sensor suites to assure quality and relevance for addressing particular science questions. Research will also include matching instrument sampling to the variable signals of interest: deep overflow events between the Maui and Kauai abyssal basins, long-term variability and trends in deep temperature and salinity, export of biomass from the shallow to the deep ocean and the seafloor, surface wave-wave interactions and associated wind wave growth and gas transfer, and marine mammal distribution and behavior.

Background

Sustained observation of the ocean is difficult. Ocean science requires new and different ways to observe the ocean, each with its own strengths and weaknesses, in order to advance our understanding and lay the foundations for predictive models and their applications. Recent technological advancements, such as mobile platforms (floats, gliders and AUVs), satellite transmission and acoustic data links are providing new acquisition methods, but sensors, instruments and platforms requiring high power, high data rates or continuous access to the water column and seafloor are as yet out of reach of these technologies. Cabled observatories – such as the ALOHA Cabled Observatory – can provide remote interactive instrument control, continuous real-time data streams and large amounts of electric power. Cabled and autonomous technologies are complementary in that the cable systems can provide the power and communications interface to subsurface autonomous fixed and mobile platforms using docking stations and acoustic communications, without the routine use of ships, thus significantly increasing the spatial footprint and the overall observing system efficiency.

Submarine cable systems have been used for science since the 1960s, with much work in Japan since the 1970s. In the 1990s, scientists in the United States began using cables to support their instrumentation and several systems were installed, e.g., LEO-15, ATOC, HUGO, and H2O (Forrester et al., 1997; ATOC et al., 1995; Duennebier et al. 2002; Petit et al., 2002). Two technologies opened the door for these observatories: remotely operated vehicles (ROVs) with power, high-resolution video, manual dexterity and long continuous work time at the ocean floor, and wet-mate electrical and optical connectors. These developments and projects, and the associated planning efforts have led directly to the just-starting NSF Ocean Observatories Initiative (OOI), part of which includes a seafloor cable system in the northeast Pacific—the RSN (regional scale nodes) adjacent to the almost-completed NEPTUNE Canada system.

As the designs of the RSN and similar or related new cable systems progress, and experience with test bed systems such as VENUS and MARS accumulates, the realities of the design, cost, and complexities – and advantages and disadvantages – of such cable systems are becoming clearer. The resulting full-scale systems coming on line, NEPTUNE Canada, RSN, and the Japanese DONET, will provide important contributions to cabled observatory efforts. At the same time the re-use of existing cables provides a complementary path to the deep ocean with minimal compromise in capability.

The ACO is a prototypical example of a deep system that uses a retired cable. The ACO architecture uses highly reliable existing transoceanic cable systems to provide power and communications bandwidth. Since the cable is already in-place and is designed to operate for well beyond its commercial lifetime, costs of conversion to scientific use (as here) are substantially lower than for new systems.

In the following section the ACO infrastructure is described, including system description, project progress, the connector problems, and the path to installation. The next Research section discusses some of the current and future science and engineering topics that the ACO has or can address. Subsequent sections provide the technical approach and the work plan we propose to reconfigure and test, deploy, and operate the ACO. After a discussion of project organization and a section on this renewal, concluding remarks are given followed by results from prior NSF support.

Infrastructure

The ACO is based on the technology used in the HUGO and H2O observatories, with improvements based on lessons learned from both (Duennebier et al., 2008). We begin with a brief review of the system elements. At the AT&T Makaha shore station, the shore power system supplies the sea cable with a constant 1.6 A at a voltage that varies depending on load, up to 1270 V for the present configuration. AT&T communications equipment provides the interface between the cable system and the Internet through the University of Hawaii (UH) via a T1 line. This includes access to the supervisory functions, such as repeater status. At the seaward end of the cable is a titanium frame with the cable termination, an Ocean Design, Inc. (ODI) hybrid electro-optical wet mateable connector (see Figure 1). Normally the sea cable will be connected to the observatory node (Figure 1 lower left). From the 840 V and 1.6 A at the end of the sea cable, the node shunt regulator supplies 48 V and 400 V at up to 800 W for the observatory electronics (50 W) and science users. The AT&T optical communications signals are converted to 100 Mb/s Ethernet. Accurate and precise timing is provided by a clock in the node in the form of an IRIG-B timing signal to the connected experiments; the absolute time is synchronized to within a millisecond with shore/GPS. The observatory node has eight ODI 12-pin electrical connectors (identical to those used on MARS, NEPTUNE Canada, and planned for RSN) supplying power, Ethernet (or other selectable protocol such as RS-232 or RS-485), and timing to science users.

In 2003, the ACO had been funded as a MRI (Major Research Instrumentation) project by NSF and was in the process of obtaining permission to use the retired ANZCAN coaxial cable that ran near Station ALOHA. Teleglobe, Inc., the main owner, went into bankruptcy and negotiations failed. We were then made aware that HAW-4, a newer first-generation optical cable system would be retired and could be made available for the ACO. A meeting of cable engineers at Rutgers in 2003 led to a specific design for cable hardware (designed mainly by Mark Tremblay, formerly at AT&T and Tyco) that would provide data transport through first-generation optical cable systems (Trembley and Duennebier, 2006). A test of the production hardware in 2006 demonstrated the capabilities by sending data from the Makaha Cable Station on Oahu to a cable station in California where it was looped-back to Oahu and recorded error-free, a round-trip path of more than 8,000 km.

Installation of the ACO was to proceed in two phases; the first would cut the HAW-4 cable, recover 20 km of cable, and move the terminated end to Station ALOHA and lower it to the bottom. With additional funding [OCE 0652430, $478K, CY2007, covering the Trembley redesign, increased AT&T station costs, and the (very) large cost increases of titanium)], this operation was accomplished in February 2007 using the USNS *Zeus* cable ship through an agreement with NSF with help from the Office of Naval Research (ONR). The cable termination was lowered to the ocean floor with a set of electronics, a hydrophone, and pressure sensor (the "Proof Module") to provide proof of concept and assurance that the system would operate as designed. Data began flowing to Oahu shortly after the sensors were in the water and ran almost continuously (brief, planned outages) until the package was recovered in October 2008.

A cruise to install Phase 2 of the ACO, the general-purpose observatory node, planned for October 2007, had to be canceled because of late delivery of faulty (obvious cracks) titanium pressure cases for the observatory electronics. A cruise in October 2008 recovered the proof module and deployed the ACO node, but failure of Ocean Design, Inc. (ODI) connectors at pressure forced its immediate recovery (see reports in Supplemental Documents). At that time we had planned to install the main ACO infrastructure, two hydrophones, an absolute pressure sensor, two ADCPs supplied by the UH Department of Oceanography, a vertical thermistor string, two MicroCATs, and an acoustic modem supplied by Woods Hole Oceanographic Institution. The thermistor string was deployed in an autonomous mode, and will record temperatures for up to three years, but the other systems could not be installed. Images from the ROV *Jason* dives are available on the Virtual Control Van.

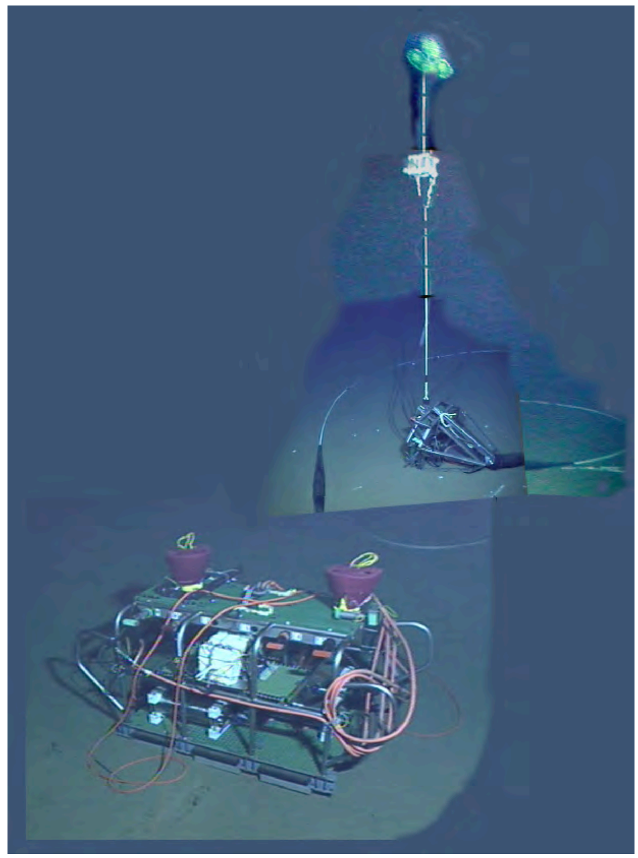


Fig. 1. A composite photograph of the ACO node at various stages during the October, 2008 deployment cruise. The package was placed within two meters of its intended location by the JASON crew using long-baseline acoustic navigation. The red hats cover the two ADCPs during deployment. The short mooring is the original proof module and seawater ground deployed in February 2007.

Four distinct failures were discovered in the ODI hardware. Several exchanges of engineers have since taken place to study the failures, and to perform and monitor testing of the failed parts. Results are reported below. Ocean Design Inc. (ODI) will replace all faulty cables and connectors at no cost to the project and support acceptance testing and the installation cruise. ODI is fully committed as a partner to making ACO work (see letter in Supplemental Documentation). They understand the need to resolve these problems in anticipation of other ocean observatories coming on-line soon. The detailed technical approach is given after discussing research using the ACO.

Research

The motivation for deploying the ACO infrastructure is to conduct research that cannot otherwise be done in the abyssal ocean. Compelling scientific research questions have been posed that only measurements from the ACO can uniquely address. There are also engineering research and development issues that can be addressed within the framework of the ACO, some related to observatory infrastructure and some related to sensors. Equally important are the scientific questions and engineering issues that will be raised by the exploratory measurements made via the ACO.

Because the effort and resources that are required to deploy the ACO are significant, it is essential that there be initial research returns from that effort. Given the long lead time required for designing, proposing, obtaining funding, and the ship and ROV scheduling needed to add experiments to the ACO, a "core" set of measurements should be made as part of the ACO deployment. These core measurements will serve the multiple purposes above, and will also provide a long time-series context for subsequent observatory-based experiments. For example, the increasing trend in abyssal salinity (Figure 2) will be monitored, along with the high frequency variations around the trend. The core measurements are summarized in Table 1.

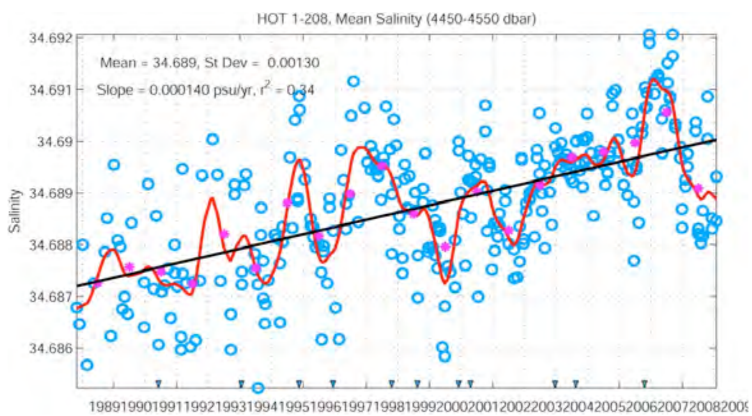


Fig. 2. Observed deep salinity variation and trend.

Table 1. ACO Core Measurements

Sensor suite	Sensors	Comments
Thermistor array/acoustic modem (TAAM) mooring from seafloor to 200 m	Seabird SBE37 thermistors 10 equally spaced (2 w/pressure) WHOI 10 kHz micromodem	A physically coupled dual mooring. Battery-operated thermistor array communicates with the ACO using Seabird inductive modem; the modem is directly connected to the observatory.
Bio-optical and visual sensors	Wetlabs FLNTU fluorometer (chlorophyll) and backscatter (turbidity) DSP&L Multi SeaCam 2060 color video camera with two LED Multi SeaLites lights	One FLNTU unit on the TAAM mooring at 200 m inductively coupled per thermistors, other on seafloor frame next to the node with camera and lights (latter fixed, orientation adjusted during deployment).
CTDs and ADCPs on node	2 each, Seabird 37 (one pumped and one un-pumped) Sontek 250 kHz	On top of node frame; CTDs swing outboard for some horizontal separation from the electronics.
Hydrophone experiment module (HEM)	Two hydrophones, bandwidth 0.01-5,000 Hz and 24-40,0000 Hz Digiquartz pressure, 16 Hz	On separate sled, can work directly off junction box (as proof module during deployment), or standard science connector on node (switched over after node deployment).

An example of an engineering issue to be addressed is the utility of acoustic Doppler measurements to obtain estimates of abyssal current profiles. We simply do not know the concentration climatology of the backscattering particles needed to obtain reasonably accurate deep ocean currents, and thus how far above the seafloor such profiles can be obtained. The two ADCPs to be deployed will allow us to conduct exploratory measurements for the design of future abyssal current measurements. Optical measurements will help quantify the backscattering particle density, which may be variably related to near-surface productivity events and to strong near-bottom current events that suspend sedimentary materials.

Another engineering issue concerns the calibration stability of conductivity sensors deployed near the bottom. Can the relatively small, but important, salinity signals that are observed in the abyssal ocean (Figure 2) be observed with high fidelity via the ACO? Are there significant differences between pumped and unpumped CTDs for achieving this objective? Will the accumulation of sediments be an important factor?

An important engineering unknown for future observatory design that needs to be explored is the range and fidelity of acoustic modem communications in the abyssal ocean. By placing an acoustic micromodem sufficiently far above the seafloor, we can listen to the received signals with the dual hydrophones that we propose as part of the core sensor suite, while the micromodem can receive direct signals from other sources, such as ships, gliders and moorings, without the complication of bottom and observatory infrastructure reflections.

The ACO core measurements should be of broad interest, not just related to a current scientific hypothesis; it is intended for these exploratory core measurements to inspire new hypotheses that may motivate new experimental proposals. Given the need to site an acoustic micromodem above the seafloor, the cost-effective addition of inductively communicating temperature sensors to the riser cable will provide the vertical structure of temperature variations around the ACO. The cold overflow events observed in the Hawaii Ocean Time-series (HOT) would be continuously monitored, with the possibility of measuring the full spectrum of thermal responses to overflow events which are likely important (Lukas et al., 2001). Given that these sensors are battery powered, their effective and efficient use will require commanding hibernation and awakening adaptively for event sampling, a compelling topic of research in itself.

The dual hydrophones will provide redundancy and some level of directionality to the acoustic measurements that have already been shown to be of interest to widely separated scientific communities. Along with absolute pressure measurements on the ACO, the variations of sea level will be measured directly, and the acoustic spectrum will provide useful constraints on the sea surface elevation spectrum. Signals from earthquakes, tsunamis, and human activities will provide information about the solid earth that will be exploited. Marine mammal acoustic signatures are already the focus of several research groups using the data obtained from the proof module deployment.

Optical sensor systems on the riser cable and on the ACO itself will help to quantify the scattering particle density, which will aid the interpretation of ADCP return intensity variations, and will help understand the CTD calibration changes due either to particle fall events that may be associated with near-surface productivity blooms, or to resuspension of bottom sediments during strong flow events. Video frame grabs will support categorization of particles and enable estimation of currents as the particles are advected within the frame.

Scientific research will include the study of cold overflow events (Figure 3), in

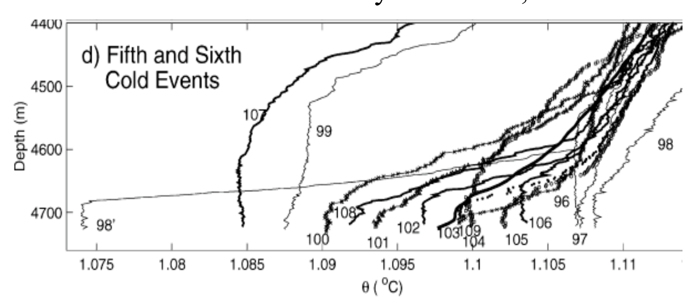


Fig. 3. The intermittent cold, deep overflow. Potential temperature profiles below 4400 m for HOT cruises 96-109. The associated salinity anomaly is positive from Lukas et al., 2001.

particular the higher-frequency temperature, salinity, and velocity signals that are associated with the events and the subsequent relaxation to more normal near-bottom thermal structure (Lukas et al., 2001). Research will continue on the surface wave-wave inter-actions that are observed in the hydrophone data (Farrell and Munk, 2008; Duennebier et al., 2009a,b; Figure 4), as well as seismic signals from various sources (Figure 5). Particle export events to the abyss will be observed, and their relationship to near-surface productivity blooms will be studied (see Figure 6).

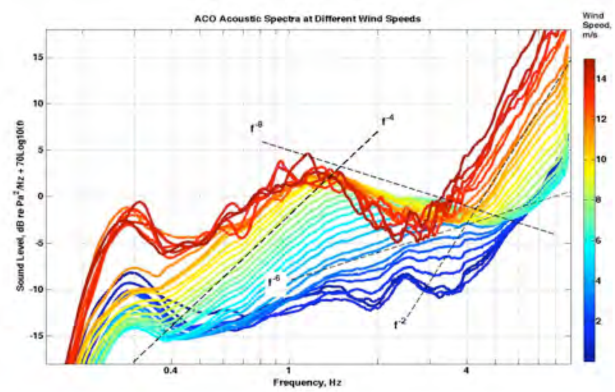


Fig. 4. ACO hourly acoustic pressure spectra are correlated with wind speed measured at the WHOI WHOTS buoy at Station ALOHA. (Duennebier et al., 2009).

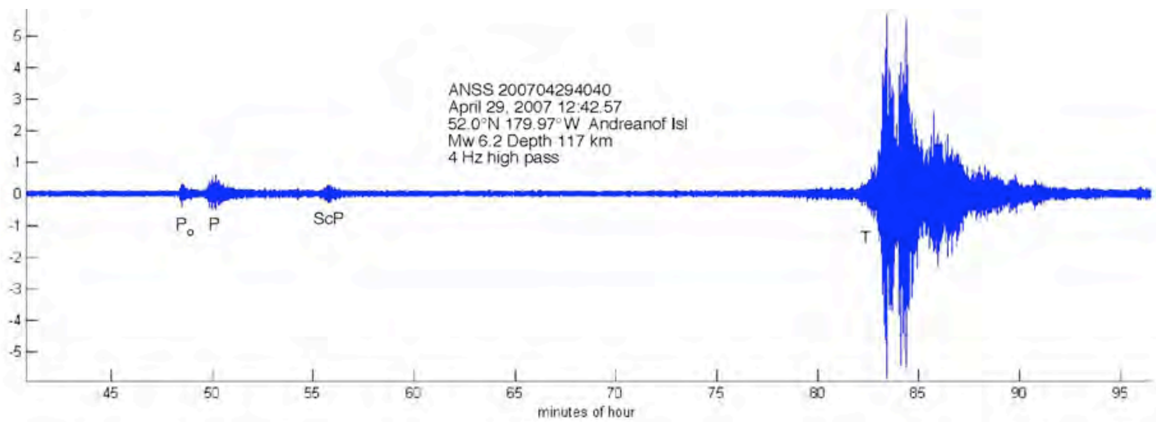


Fig. 5. Typical recording of an Aleutian earthquake by the ACO proof hydrophone. 4 Hz high pass filtered.

Examples of Future Research Directions

While we do not know the full variety of innovative ideas that will be proposed to take advantage of the ACO infrastructure in the future, we provide some examples of viable future experimental research activities that have been extensively discussed. They illustrate the transformative nature of the observatory approach to deep ocean research.

Mooring sensor systems. The mooring sensor network with profiler that was originally proposed for installation at the ACO (Figure 7) is now being proposed for installation at the operational MARS observatory (the ALOHA-MARS mooring (AMM), B. Howe PI). When the ACO is operational, a similar if not identical mooring system will be proposed for installation at ACO to address numerous science goals. In the meantime, the "HOT Profiler" mooring project (M. Alford, PI, B. Howe and T. McGinnis co-PIs) will install an autonomous battery powered (3 l-m steel spheres with alkaline batteries) mooring system with a buoyancy-driven profiler, using an inductive power transfer system similar to the AMM. This mooring will be deployed in winter 2010 with enough on-board energy to run the profiler and other systems continuously for 1 year. It will have several means to communicate. First will be an acoustic modem that can "talk" to with the ACO acoustic modem and hydrophones as well as with the ship during routine ALOHA-HOT visits. The second will be via a small, slack tethered surface buoy with GPS, Iridium and freewave radio. Ultimately, the cabled mooring system in Figure 7 will enable high-resolution vertical profiles of physical, chemical, and biological quantities over the entire water column. This will eventually allow shifting some of the burden of the routine HOT sampling to this automated system (with much improved sampling), freeing the human and ship resources to focus more on new, more difficult and challenging sensors and sampling.

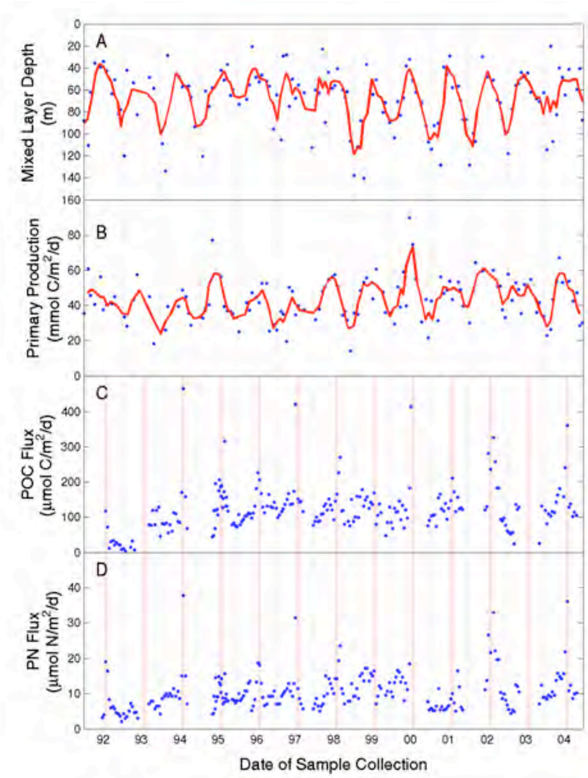


Fig. 6. Deep export events. A composite of key environmental variables observed at Station ALOHA for the period 1992-2004. [A] Mixed-layer depth, [B] Primary production, [C] POC flux at 4000 m, [D] PN flux at 4000 m. The data in [A] and [B] were collected on approximately monthly Hawaii Ocean Time-series cruises (closed blue circles) and the red trend lines are 3-point men values for each parameter. The data in [C] and [D] were collected in bottom-moored time-series sediment traps. The lightly shaded period in [C] and [D] corresponds to the period 15 July – 15 August when deep sea particulate matter fluxes are at their annual maxima. (Courtesy of D. Karl and R. Letelier.)

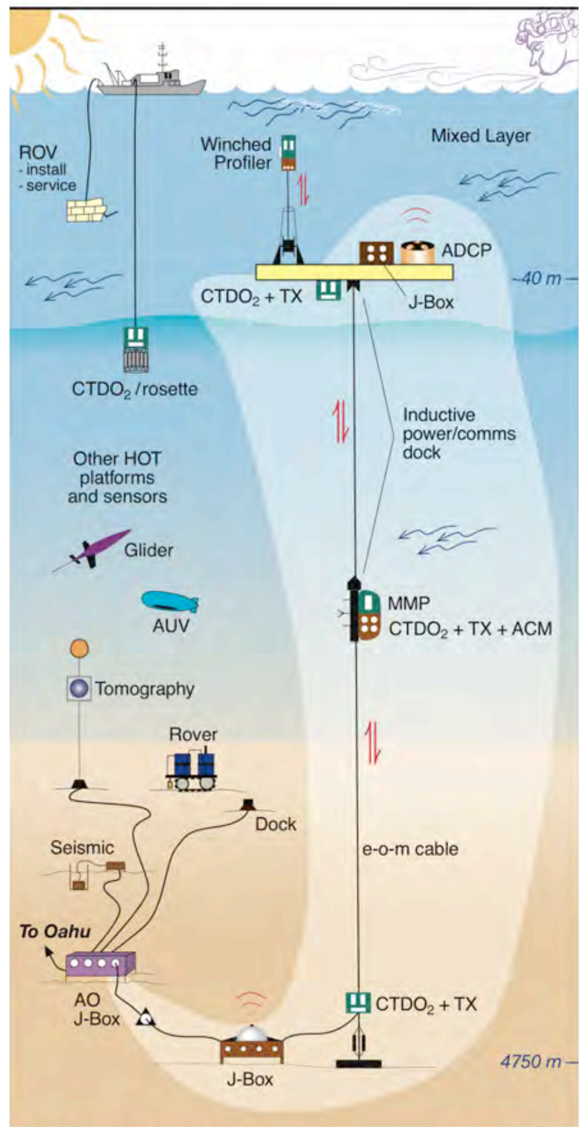


Fig. 7. The ALOHA mooring sensor network. The lightly shaded area indicates the 2003 proposed moored sensor network.

Tsunamis. The absolute pressure sensor in the Phase-1 system had a resolution of better than 5 mm of equivalent sea level, enough to detect a small tsunami, although none were observed during the recording period. A potential problem of using pressure sensors for tsunami detection is that the pressure signal from seismic Raleigh waves generated by tsunamigenic earthquakes recorded at the ocean floor can be several centimeters of equivalent ocean depth in amplitude at the expected time of arrival of tsunami. Obscuration of the tsunami pressure signal could lead to mis-identification of signals and possible false alarms. Tsunami detection might be improved with near-bottom current measurements, since the horizontal motion of the water column (above the benthic boundary layer) is expected to be far larger than the vertical motion during a tsunami. This hypothesis is one of the motivations for installing both a pressure sensor and ADCP at the ACO.

Hydrophone array. One of the most useful and robust sensor systems that can be installed at the ACO is a hydrophone array. In addition to surface environmental studies discussed above, it would be used for tracking whales, ships, and moving acoustic sources near the ACO. Although the bottom is well below the reciprocal depth of the SOFAR channel, we are able to hear ships from as far away as 160 km and T-phases from earthquakes around the Pacific Rim. During the initial 20 months of recording the calls of fin, blue, humpback, minke, and sperm whales and as well as porpoises were identified. The minke whale calls heard at ACO are the subject of research by J. Oswald (Hawaii Institute of Marine Biology, UH) and Tom Norris (Bio-Waves, Inc.) funded by ONR (Figure 8). A suitable array is under consideration, but will not be proposed until the observatory is in operation; rather, two hydrophones that are already available will be installed to provide crude directionality information.

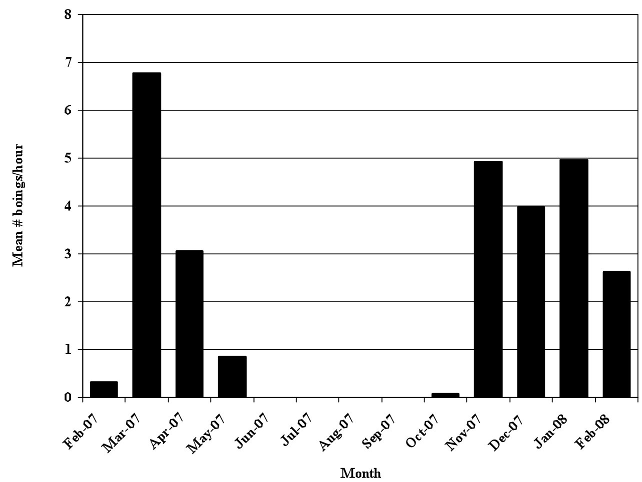


Fig. 8. Mean number of minke whale "boings" per hour detected at Station ALOHA during each month. Boings were heard from October 22, 2007 – May 21, 2007 and not at all during June through September. This seasonality closely matches that of humpback whales, who migrate to Hawaiian waters to breed during the winter and spring. From Oswald et al., 2008, 2009.

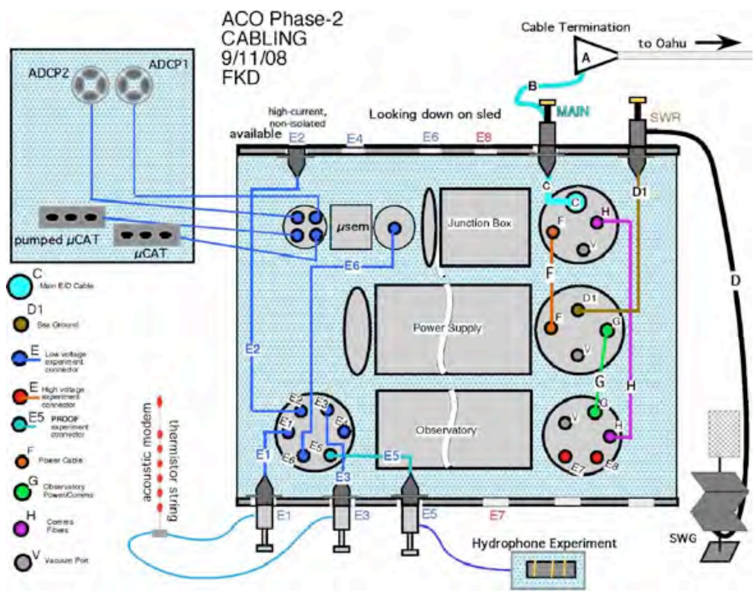
Technical Approach

We describe how we will reconfigure and test the system to assure a high probability of success. Figure 9A shows a schematic of the system ready for deployment in October, 2008. Figure 9B shows the planned re-configuration. Details of the deployment cruise and connector failures are given in the respective reports, included as supplementary documents.

The immediate cause of failure was cable assembly H. This assembly linked the junction box to the observatory pressure case with 4 optical fibers carrying 100 Mb/s Ethernet, using dry-mate connectors at each end (only 2 of the 4 fibers were used). The pins in each connector are spring loaded to permit the faces of the mating fibers to touch with the correct contact force. In this case, the high ocean pressure distorted and caused flow of material around the base of the pins causing them to move apart and bind, thereby breaking the optical paths. Further, oil leaked from the oil-filled hose into one of the connectors. The immediate solution that will be implemented is to install an optical-electrical Ethernet converter in the junction box and replace this cable with an all-electrical cable/connector assembly.

Additional failures involved cable assembly B1 with hybrid optical-electrical connectors, connecting the sea-cable to the proof module/observatory. This assembly was working upon recovery, as

A.



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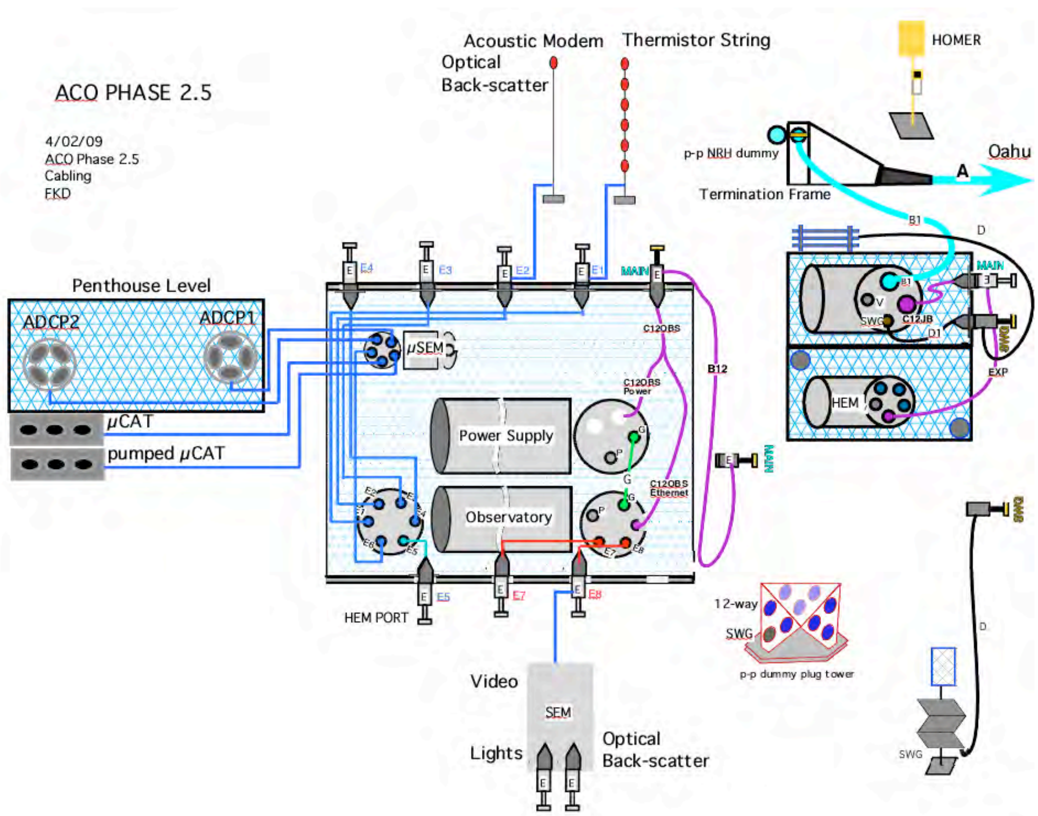

Fig. 9. ALOHA Cabled Observatory node schematic. A – as ready for Phase 2 deployment in October 2008. B – as planned for Phase 2.5 deployment in July 2010 as proposed here. Shown is the HEM (hydrophone experiment module) EXP cable connected to the "main" port on the junction box as it would be on deployment for system testing; subsequently cable B12 would connect to the "main" port and the HEM to port E5 on the observatory node.

demonstrated by the functioning proof module. However, the first sign of trouble was the visible drops of oil leaking from the sea-cable connector when it was disconnected at the start of the recovery operation and raised to the same elevation as the proof module. Afterwards in the lab on the ship, we found about a cup of oil that had leaked from the oil-filled hose into the proof module. Further, some seawater that apparently had penetrated the hose and had lain dormant in a low spot, shifted and caused an electrical short on deck. Lastly, the same connector B1 required many attempts before finally mating. Results of the recent CT-scans indicate that the cam mechanism that controls the rolling seals does not always work as intended, causing the connector to jam one inch short of mating.

Since all the ACO cable/connector assemblies were made c. 2005, ODI has implemented improved quality control practices and testing (e.g., helium leak testing) that should significantly lower the risk of the pressure-related failures. ODI, in consultation with UH engineers, is working toward a solution to the rolling seal mating problem. ODI will be hosting a workshop in late 2009 to review status and solicit the constructive criticism of engineers from many of the on-going cable projects (ACO, NEPTUNE Canada, RSN, MARS, VENUS, and DONET).

To further reduce risk, we will simplify the system by making it more modular, moving the junction box (with the AT&T repeater/regenerator electronics delivering 100 Mb/s Ethernet) off the main observatory node frame to a nearby sled by itself with only one electrical-only connection to the node. The electrical voltage is 840 V, well within the specifications (5 kV) of the observatory standard ODI 12-pin wet-mateable connector. Ethernet has been used through these connectors many times. With this configuration, the highly reliable junction box can remain in place with the proof module (or any other low power experiment) if the observatory node needs to be recovered for repair or expansion of capability. Ideally, once the B-A connection is made between the junction box and the sea cable, the connection will never have to be broken again, reducing the risk of encountering the physical mating problem in the future.

The system is currently running in a state of readiness in Howe's lab space, with electronics and sensors running off a laboratory power supply. Modifications, integration, and testing of new connector/cable assemblies and other parts will proceed incrementally. As was done previously, pressure cases will be sealed two months prior to deployment in the final configuration fully tested with the actual power supply (requires cooling water). During this time period, the engineering documentation and project web page will be improved and updated.

Work Plan

The work plan is broken into three chronological segments:

- Reconfigure the system with new connector/cable assemblies, perform minor modifications, and re-test the system prior to deployment (year 1),
- Install the node and science experiments (Phase 2.5) of the ACO (beginning of year 2, July 2010), and
- Testing and transition to operations (Phase 3) year 2.

Given the requested start date of 1 July 2009, the system will be ready to deploy by early 2010. After this, we will take the first available opportunity in the UNOLS ship / ROV *Jason* schedule to deploy the system (see ship request form). For planning, we assume the deployment will be early in year 2 (i.e., July 2010 or after) with testing and operations for the balance of year 2. It should be understood, though, that scheduling the ship/ROV is uncertain and deployment may occur anytime from early calendar year 2010 into 2011. We will work closely with the NSF program officers and UNOLS to work out these scheduling issues.

Reconfigure and shore-side testing

ODI connectors. The ODI optical cable/connector assembly failure that ended the Phase-2 deployment last year will be replaced with an electrical-only assembly and fully tested. The other ODI components (connectors passing oil under pressure and connectors that connected with difficulty) will be replaced by ODI and fully tested prior to installation, including testing at the factory prior to delivery as well as at UH. The system will be modified as shown in Figure 9B to eliminate all optical connectors except the main hybrid ODI electro-optical cable/connector assembly, which is required for connection to the main sea cable termination on the ocean floor; this change makes the system more modular. These changes should significantly enhance reliability with no functional changes or modifications to pressure vessels other than changing connectors. All ODI connector and cable assemblies will be pressure tested at ODI and UH.

Sensors. Sensor details have been given in Table 1. As also planned for the October 2008 deployment, the ACO node frame will be deployed with two upward looking ADCPs and two MicroCAT CTDs connected to the µSEM (micro science experiment module) that is dry-mate connected to the main observatory node pressure case. There will be two co-joined 200-m high cabled components (on separate experiment ports) integrated into the thermistor array/acoustic modem (TAAM) mooring system. One cabled component will have a ten-element thermistor array, all self-powered with batteries for at least two years but communicating in both directions through the ACO via an inductive modem; the second will power and provide two-way communications with a 10 kHz WHOI micromodem system (L. Freitag, personal communication). The acoustic micromodem will communicate with nearby autonomous systems such as the NSF-funded HOT profiler mooring to be installed in 2010 for a year (M. Alford, APL-UW). The original hydrophone/pressure proof module will be reconfigured to use the standard 12-pin connector, so it can connect either to the junction box (and be powered by it during deployment to verify functionality) or to an experiment port on the observatory node (the hydrophone experiment module, HEM). It now has two hydrophones separated by 1.2 m with combined effective bandwidth of 0.01 Hz to 40,000 Hz; sampling rate can be selected up to 192 kHz. Two optical fluorometer/backscatter sensors and a video camera/light system will be included; the camera system and one optical sensor will be on sled just next to the node. The latter will require a SEM with pc-104 and video server. All these sensors/instruments/experiments will be fully tested with the complete Phase-2.5 system well prior to deployment, with the responsible co-PIs obtaining test data over the Internet. Similar testing was performed prior to the October 2008 cruise.

Data management. The development of the data management components required for a fully operational ACO will be finished. These include real-time data communications, command and control interface, real-time data management, automated data processing, near-real time data services, and data archival. Analysis of test data and subsequent in situ data will provide real tests of the data management components, and will result in feedback to the configuration of the data management system.

Installation

We assume installation will be at the beginning of year 2, July 2010. This work will include mobilization, the cruise itself (10 days on station with contingency), demobilization, and a commissioning period (nominally one month) when all observatory functions are tested and verified, and a baseline of operations established. Mark Trembley, the retired AT&T engineer most knowledgeable about the telecom portion of the system, will be available for consultation during this period.

Operations

With deployment at the beginning of year 2, we plan to transition from testing to operation of the observatory for the remainder of the 2nd year, through June 2011. During this time proposals will be written by us to obtain longer-term funding for continued operations, and written by the members of the oceanographic community to add new science experiments. We will reactivate the ACO Science and Technology Advisory Committee, and coordinate with the OOI as their operations gear up. Operational costs will include rental fees for the shore station space, liability insurance, a T1 line to the UH campus from the shore station, and IRIS fees (Incorporated Research Institutions for Seismology; for hydrophone data, below).

Data management will involve monitoring of data transmission quality and engineering diagnostics, automated and delayed mode processing of core observatory measurements, data archival and web-based dissemination of appropriate datasets. Data will be archived locally on a RAID system, with controlled public Internet access (i.e., registered users for data, while we gauge demand). Hydrophone and video data will form the largest volume. Hydrophone data will be streamed using the software tools from Phase 1. At the Makaha cable station, the data from the two hydrophones will be digitally filtered with low-pass cut-off frequencies of 5 kHz and 24 kHz before transmission to UH. A modest amount of processing of the higher frequency data is possible at the shore station (as was done in the past). At UH, a gain and frequency adjusted stereo data stream will be formed and streamed (24 kHz sample rate); also, low frequency (160 Hz sample rate) data will be sent to IRIS (Incorporated Research Institutes for Seismology) in the miniSEED format along with the dataless SEED metadata, as was done with H2O data. Video data will be acquired only intermittently so as to minimize any possible detrimental effects of the lighting. Software tools used at APL-UW for the AMM camera system will be used for acquisition and archiving; the sampling protocol will be developed as part of the research. As data are acquired and archived, the documentation and web page will be kept up to date to facilitate use by the broader community.

Education and Outreach

The ACO Program will coordinate with the academic departments in the School of Ocean and Earth Sciences and Technology (SOEST) to select one individual for an undergraduate research position. One graduate student will be supported in the Department of Ocean and Resources Engineering. An invitation will be offered for undergraduate and graduate students to participate in the installation cruise. The 12-day-long 2008 cruise hosted one post-doctoral researcher, two graduate students and three undergraduate students. These students gained valuable marine research experience observing and helping with the installation operations, and working with and collecting samples with *Jason*. We expect to repeat this.

As more experiments and instrument systems are added to the ACO, we expect individual investigators to obtain funding for their research programs, including education and outreach. The ACO provides the infrastructure to make such programs possible, but the programs themselves will be driven by the vision of the particular investigator.

The ACO web site (http://www.soest.hawaii.edu/GG/DeepoceanOBS/aco_home_page.htm) provides background information for the general public and scientists interested in the data and in designing and installing experiments. Until the system went down in October 2008, the site provided a real-time high quality audio stream that could be easily accessed by the public. The site is still active with samples of archival data.

Project Organization and management

With Fred Duennebier's change in status to emeritus professor in July 2009, Bruce Howe will assume PI responsibility for the project. Howe has extensive experience in cable systems from various projects including ATOC (Acoustic Thermometry of Ocean Climate), planning and design of the NEPTUNE system (now morphed into the NSF OOI RSN and NEPTUNE Canada), design and development of cable power systems (used in MARS and NEPTUNE) and mooring sensor systems (the ALOHA-MARS Mooring and the HOT Profiler projects). Howe's primary task as PI will be to oversee the engineering effort. He will be supported by co-PIs Duennebier, Lukas and Karl. Duennebier will provide system corporate memory, advise on the reconfiguration and testing, and will analyze the acoustic and pressure data in the context of the wave-wave interaction discussion above as well as for seismic T-phases. Lukas is responsible for the data management and will organize the ACO Science and Technology Advisory Committee to help guide the further development of the ACO as a community resource. He will also analyze the CTD, ADCP, and thermistor string data. David Karl will work with Howe and students to process and analyze the optical and video data. Howe will advise the graduate student and supervise the undergraduate.

Project meetings will be held monthly and engineering meetings weekly. Results from past and on-going data analysis will be presented at national meetings and submitted for publication.

Renewal proposal

This project has experienced a number of delays with causes beyond our control – the change in the telecommunications cable, developing a technical solution to using the first-generation optical fiber cable, flawed titanium pressure cases, and finally the failed connector/cable assemblies last October. The obvious lesson from last October's experience is to test more and to look for all ways to keep the system as simple as possible. ODI's active participation, involvement, and commitment will ensure more sophisticated and thus rigorous testing; the reconfiguration will further simplify the system.

The original MRI grant was for $2M (NSF OCE 0216164). The parent of this present request was a new grant of $478K (OCE 0652430, effectively an extension of the MRI grant). These funds carried the project through last October, with in-kind engineering support from UH. The objective then was simply to install the system; operating funds were not included. In this renewal proposal, the scope is expanded somewhat to include one transition year to operations as we feel this is only reasonable to allow time for subsequent proposals for operations and science to be written, submitted, and funded. At this time it is premature to give a detailed management plan and budget for long-term continuing operations; rather, we present a preliminary plan and budget in the Supplementary Documents section.

Assuming success here, ACO will have cost a total of $3.3M. This can be compared with the cost of the NSF-funded MARS system in Monterey Bay at $13.5M, NEPTUNE Canada ~$100M, and NSF RSN ~$100M. Obviously, the capabilities of these systems are different, but the ACO will be the only open ocean abyssal observatory available to the ocean science community.

Concluding remarks and broader impacts

Long, sustained time-series of ocean observations only become more valuable with time. The exceptional record from HOT at Station ALOHA is the perfect example of this. HOT is successful because it maintains the continuity and is constantly improving the high quality base time series, and thus it acts as a magnet for projects with tremendous synergy, e.g., the WHOTS meteorological/upper ocean mooring, the Center for Microbial Oceanography: Research and Education (C-MORE, a NSF Science and Technology Center (STC), also funded by three foundations) which uses Station ALOHA as its primary field site, and the ALOHA Cabled Observatory. The ACO when completed will provide the *transformative* infrastructure necessary to continue and improve the base time series, while enabling the expansion of the spatial and temporal sampling needed to address ever more difficult questions.

Upon successful deployment of the ACO node, we believe that the community will respond and submit a number of proposals to use the system. A benthic monitoring system to make long-term sediment flux and benthic ecology studies has been proposed by K. Smith (MBARI). The PIs and colleagues will be proposing to extend the spatial footprint of the node and mooring systems using bottom HPIES (horizontal electric field (barotropic velocity), pressure, and inverted echosounder) and gliders; the latter will not only sample the ocean directly, but provide "data mule" service for the HPIES and other autonomous instruments in the area. Active and passive acoustics will also be proposed to extend the footprint to basin scale a la ATOC. In the longer timeframe we envision the AUV docking stations mentioned in the introduction, with vehicles performing maintenance tasks as well as science missions.

At the time of this writing, the NSF OOI is undergoing a reconfiguration that reduces the cabled components (to only two nodes on the RSN) in favor of moored systems that do not supply power to the seafloor and have limited bandwidth and require considerable maintenance. Thus, the ACO emerges as one of the few sites in the global ocean that can provide sustained low-maintenance observations, and the only one at such depth. The expectation is that over time, the cabled systems such as ACO that are not explicitly part of the OOI and yet extend the scope and serve exactly the same goals and objectives, will be eventually incorporated into the OOI or a follow-on initiative, e.g., "OOI2." (NSF OCE and EAR are starting to explore the expansion of deep-ocean sensing.) This process is already in progress in terms of physical interfaces (e.g., science port connectors and pin assignments) and there are efforts to reach consensus on cyberinfrastructure. We will ask our Advisory Committee to help in this regard.

As we said above, sustained observation of the deep ocean is difficult and the problems with the ODI connectors are just one reflection of this. Given the other ocean observatories which are in-progress or are being planned, and which depend on these or similar connectors, we need to address these issues quickly; doing so at a relatively inexpensive observatory will be beneficial to all cabled observatory systems.

The ACO is a proof-of-concept system for cable re-use. The existence of more than 35,000 km of in-place retired or soon-to-be-retired first-generation commercial cable systems are a potential resource for marine science. Several of these cables go through regions of interest, such as south of the Aleutian Islands, and across the equator to New Zealand, where they could be effectively utilized in place. In many cases, the precise location is less important than the supply of reliable power and communications. These systems offer potentially lower operational costs and far more data bandwidth and electrical power than autonomous buoy observatories and might be considered when planning OOI2.

Results from Prior NSF Support

The NSF grant, SENSORS: Collaborative Research: ALOHA Mooring Sensor Network and Adaptive Sampling, supported the development of the ALOHA-MARS mooring system (AMM) (OCE-0330082: PI: B. M. Howe. Co-PIs: R. Lukas, E. Boss, J. Gobat, J. Mercer, and T. McGinnis; Amount: $2,937,977; Period: 10/01/2003-09/30/2009). This mooring system connects to seafloor cabled observatories [e.g., the ALOHA Cabled Observatory (ACO) and the NSF OOI MARS and Regional Scale Nodes (RSN, a.k.a., NEPTUNE)], extending the power, communications, and timing infrastructure through the water column. The plan (given the uncertainty in the ACO status at the time) was to deploy at the MARS cabled observatory in Monterey Bay but delays in the latter made this impractical. An equivalent test node (same connectors, etc.) was created at the Seahurst Observatory in Puget Sound. The project is now closing after extensive, successful testing of the system at this 30 m depth site. A prototype data management system was developed. An overview can be found in Howe et al. 2007; see the project web page at http://alohamooring.apl.washington.edu/. A NSF proposal is under review to connect the AMM to the MARS node to study the feedback between circulation and tidal mixing in Monterey Bay.

Since October 1988, the Hawaii Ocean Time-series (HOT) program has investigated temporal dynamics in biology, physics, and chemistry at Station. ALOHA (22°45'N, 158°W), a deep ocean field site in the oligotrophic North Pacific Subtropical Gyre (NPSG). The most recent 6-year phase of this project has been supported by two separate but integrated NSF grants, which focus on biogeochemical and physical processes, respectively:

1. Collaborative Research: Hawaii Ocean Time-series Program: Biogeochemistry and Ecology Component (OCE-0326616: D.M. Karl, PI, R.R. Bidigare and J.E. Dore, co-PIs, 09/03-07/09, $5.3M; OCE-0324666: M.R. Landry, PI, 09/03-07/09, $611K; OCE-0326419: R.M. Letelier, PI, 09/03-08/09, $486K).
2. A Time-Series Study of Ocean Climate Processes in the North Pacific Subtropical Gyre (OCE-0327513: R. Lukas, PI, 10/03-09/09, $2.8M) and its supplement, Hawaii Ocean Timeseries: Study of Subtropical Gyre Physics and Climate Interactions (OCE-0752606: R. Lukas, PI, 09/08-02/10, $772K).

HOT conducts near monthly ship-based sampling and makes continuous observations from moored instruments to document and study NPSG climate and ecosystem variability over semi-diurnal to decadal time scales. More than 400 peer-reviewed journal articles and invited book chapters have resulted; nearly half of this total has been published during the most recent funding cycle (2003-2009). Approximately 60% of the journal articles to date were authored by scientists outside UH. HOT data are rapidly disseminated to the public via open-access, user-friendly websites. In 2008 alone, these sites have received more than 350,000 queries. HOT was founded by University of Hawaii (UH) scientists and is centered at UH, yet the program has attracted a growing and increasingly diverse cadre of investigators from the U.S. and abroad. They have used HOT data and benefited from the logistical and intellectual support of HOT scientists and staff. For example, Church currently receives NSF funding (OCE-0425363: PIs J. Zehr, M. Church, and J. Montoya, 08/04-7/09, total award $539,655) for a collaborative project at UCSC aimed at evaluating temporal variability in N2 fixation and diazotroph diversity at Station ALOHA. The project has merged molecular-based and biogeochemical approaches to examine the dynamics of N2 fixing bacteria in the North Pacific Ocean, relying on logistical support from HOT, including routine shipboard sampling and use of HOT equipment and instrumentation. Moreover, the HOT core dataset provides invaluable context on habitat variability at Station ALOHA that has proven invaluable for this project. Over the past 20+ years, HOT has provided ship time and/or sample collections to >100 researchers from >50 institutions. NSF alone has supported more than $60M in HOT-related research beyond the core measurement program; approximately 70% of these funds were awarded to institutions other than UH. In addition to maintaining the long-term continuity of the HOT measurement program and supporting the research projects of other investigators, HOT PIs are committed to education, outreach, and training at all levels. HOT has provided unique learning opportunities for secondary, undergraduate, graduate, and postdoctoral students from Hawaii and around the world, including field, laboratory, and classroom experiences. At least 18 Ph.D. and numerous M.S. students have been awarded degrees based on HOT-related research projects. Collectively, graduate and undergraduate students have logged >3000 days of at-sea field experience by participating in HOT cruises.

References

ALOHA Cabled Observatory

Project and science: http://kela.soest.hawaii.edu/ALOHA/

Engineering: http://www.soest.hawaii.edu/GG/DeepoceanOBS/aco_home_page.htm

ATOC Instrumentation Group: B. M. Howe, S. G. Anderson, A. Baggeroer, J. A. Colosi, K. R. Hardy, D. Horwitt, F. Karig, S. Leach, J. A. Mercer, K. Metzger, Jr., L. O. Olson, D. A. Peckham, D. A. Reddaway, R. R. Ryan, R. P. Stein, K. von der Heydt, J. D. Watson, S. L. Weslander, and P. F. Worcester, Instrumentation for the Acoustic Thermometry of Ocean Climate (ATOC) prototype Pacific Ocean network, *Proceedings, Oceans '95, MTS/IEEE, October 9–12, San Diego, CA*, 1483–1500 (IEEE, New York, 1995).

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Trembley, M. D., and F. K. Duennebier, Format and bit rate independent communications over regenerated undersea fiber optic cable systems, *Proceedings of the Scientific Submarine Cable 2006 Conference*, 182–185, Marine Institute, Dublin Castle, Dublin, Ireland, 7-10 February 2006.

BIOGRAPHICAL SKETCH
Bruce M. Howe

Professional Preparation

Stanford University	Mechanical Engineering, Fluid Mechanics	B.Sc.	1978
	Engineering Science, Fluid Dynamics	M.Sc.	1978
University of California, San Diego	Oceanography, Ocean Acoustic Tomography	Ph.D.	1986

Appointments

University of Hawaii

Ocean and Resources Engineering Department, School of Ocean and Earth Science and Technology

2008 – Research Professor

University of Washington

Applied Physics Laboratory, College of Ocean and Fishery Sciences

2008 – Affiliate Principal Oceanographer

1998 – 2008 Principal Oceanographer; 1992 Senior Oceanographer; 1987 Oceanographer

School of Oceanography, College of Ocean and Fishery Sciences

2008 – Affiliate Professor

1994 – 2008 Research Associate Professor; 1988 Research Assistant Professor

Department of Electrical Engineering, College of Engineering

2008 – Affiliate Professor

2005 – 2008 Adjunct Research Associate Professor

University of California, San Diego

1986 – 1987 Postgraduate Researcher, Institute of Geophysics and Planetary Physics

1981 – 1986 Research Assistant, Scripps Institution of Oceanography

Universität Karlsruhe: 1979 – 1981 Research Associate, Institut für Hydromechanik

Stanford University: 1976 – 1979 Research Assistant, Department of Civil Engineering

Scientific Expeditions

Participant in 33 cruises with 444 days at sea or in the field, 15 cruises as Chief Scientist, one each using DSV *SeaCliff*, the ATV ROV, and R/P *FLIP*; cable laying and ATOC source installations

Publications - Author or co-author of 53 refereed papers and 189 other works.

Selected Publications

Howe, B. M., and T. Chereskin, Oceanographic Measurements, Springer Handbook of Experimental Measurements, Springer Berlin Heidelberg, Chapter 18, pp 1179-1217, DOI 10.1007/978-3-540-30299-5_18, 2007.

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Other Publications

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Synergistic Activities (selected)

2008 –	Member, International Ocean Network Committee
2006 – 2008	Project Scientist, Regional Scale Nodes, NSF Ocean Observatories Initiative
2005 – 2007	ORION Engineering Committee, Member
2003 –	Integrated Acoustics Systems for Ocean Observatories, Co-chair of ASA Committee
2003 –	Current Measurement Technology Committee, Member
2000 – 2003	Acoustical Oceanography Technical Committee, ASA, Member
1997 – 2008	NEPTUNE planning and technical activities
1991 – 1995	Tomographic Data in Ocean Models, Chair of ONR Committee

<u>Professional Societies</u>

American Geophysical Union · American Meteorological Society · Sigma Xi
The Oceanography Society (charter life member) · IEEE Oceanic Engineering Society
American Association for the Advancement of Science · Acoustical Society of America

Collaborators and Other Affiliations

P. Arabshahi (UW), R. Andrew (UW), A. Baptista (OHSU), E. Boss (UMaine), Y. Chao (JPL/UCLA), B. Cornuelle (SIO), J. Delaney (UW), B. Dushaw (UW), M. Dzieciuch (SIO), A. Gray (JPL), R. Lukas (UH), D. Martin (UW), T. McGinnis (UW), J. Mercer UW), S. Roy (UW), W. Munk (SIO), P. Worcester (SIO)

Graduate and Postdoctoral Advisors

Graduate Advisors: MSc: Robert Street (Stanford). PhD: Walter Munk (SIO) and Peter Worcester (SIO).
Postdoctoral: Peter Worcester (SIO)

Thesis Advisor and Postgraduate-Scholar Sponsor

PhD: Chris Walter (1999). MSc: Keith Curtis (1998), Michael Zarnetske (2005)
Postgraduate: Brian Dushaw (UW).

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Geophysicist (R-5), 1984-present
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EDUCATION:

B.S., Physics, Trinity College, Hartford, CT, 1965
M.S., Geophysics, University of Hawaii, Honolulu, HI, 1968
Ph.D., Geophysics, University of Hawaii, Honolulu, HI, 1972
Graduate Advisor: Dr. George Sutton

RECENT SELECTED ACTIVITIES:

- Principal Investigator: ULF/VLF Sensor System Development, U.S .NAVY, 1988-1992.
- Principal Investigator: Low Frequency Underwater Sound, ONR, 1990-1992
- Principal Investigator: HUGO Project, NSF, 1990-1999.
- Chairman, Dept. of Geology & Geophysics, University of Hawaii, 1993- 1996
- member, NASA Mars Science Working Group, 1989-94.
- member, JOI Ocean Seismic Network Steering Committee, 1991-94
- member, IRIS Ocean Cable Re-use Committee, 1994-1998
- member DEOS Executive Committee, 1997-2000
- Principal Investigator: Loihi July, 1996 Seismic Crisis Response (NSF, 1996-7)
- Chief Scientist: Loihi Rapid Response Cruise, August, 1996.
- Co-Investigator: Hawaii-2 Observatory Project, 1995-2004.
- NSF: SCOTTS Steering Committee. member. 2002
- Member: OBSIP Steering Committee, 2001-2003
- National Research Council Committee on Implementation of Ocean Observatories, member, 2003
- DEOS Cable Re-use Committee. member, 2003
- Principal Investigator: NSF ALOHA Cabled Observatory 2002-2009

GRADUATE STUDENT COMMITTEES:

sat on 48 student committees since 1979

GRADUATE STUDENT FACULTY ADVISOR:

advise/have advised 16 graduate students since 1982
PhD students: R. Estill, J. A. Carter, P. Milholland, R. Cessaro, N. J. Letourneau, C. Bryan, D. Bergersen, J. Caplan-Auerbach

RECENT COLLABORATORS: P. Bromirski, SIO; A. Malahoff, SOEST; R. Butler, IRIS; A. Chave, WHOI, R. Lukas, SOEST, Bruce Howe, SOEST

FIVE RELATED PUBLICATIONS:

Duennebier, F. K., D. W. Harris, J. Jolly, **Aloha Cabled Observatory will monitor ocean in real time**, Sea Technology, V 49-2, p. 51-55, February, 2008

Harris, David W. and Fred K. Duennebier**, Powering Cabled Ocean Bottom Observatories,** IEEE Jnl. Ocean Engineering, V 27, # 2, pp 202-211, Apr 2002

R. Petitt, D. Harris, B. Wooding, J. Bailey, J. Jolly, E. Hobart, A. Chave, F Duennebier, R. Butler, A.D. Bowen, and D.R. Yoerger**, The Hawaii-2 Observatory,** IEEE Jnl. Ocean Engineering, V 27, # 2, pp 245-253, Apr 2002

Duennebier, F.K. , David Harris, James Jolly, Jackie Caplan-Auerbach, Robert Jordan, David Copson, Kurt Stiffel, James Babinec, Jeff Bosel, **HUGO: The Hawaii Undersea Geo-Observatory**, IEEE Jnl. Ocean Engineering, V 27, # 2, pp 218-227, 2002.

Bromirski, Peter, F.K. Duennebier, R. Stephen, **Mid-ocean Microseisms**, Geology Geophysics Geosystems, V 6, # 4, 20, p 1-19, Apr, 2005.

FIVE OTHER SIGNIFICANT PUBLICATIONS:

Duennebier, F.K., David W. Harris, James Jolly, James Babinec, David Copson, Kurt Stiffel, **The Hawaii-2 Observatory Seismic System,** IEEE Jnl. Ocean Engineering, V 27, # 2, pp 212-217, Apr 2002

Bromirski, P., F. K. Duennebier, **The Near-Coastal Microseism spectrum: spatial and temporal wave climate relationships** Jnl. Geophys. Res, V 107, No. B8, 2166, doi:10.1029/2001JB000265July, 2002.

Duennebier F. K., G. H. Sutton (2007), Why bury ocean bottom seismometers?, Geochem. Geophys. Geosyst., 8, Q02010, doi:10.1029/2006GC001428.

Caplan-Auerbach, Jacqueline , Duennebier, Fred , 2001, - **Seismicity and velocity structure of Loihi seamount from the 1996 earthquake swarm**, *Bull. Seis. Soc. Am.*, 91(2), 178-190.

Caplan-Auerbach, J., C. G. Fox and F. Duennebier, **Hydroacoustic detection of submarine landslides on Kilauea volcano**, *Geophys. Res. Lett.*, 28(9), 1811-1814, 2001..

BIOGRAPHICAL SKETCH

DAVID MICHAEL KARL
Professor of Oceanography
SOEST, University of Hawaii, Honolulu, HI 96822
phone: 808-956-8964 / fax: 808-956-5059 / email: dkarl@soest.hawaii.edu

A. EDUCATION

State University College at Buffalo, New York
B.A. degree, December 1971, *magna cum laude*
Major: Biology

Florida State University, Tallahassee, Florida
M.S. degree, August 1974
Major: Biological Oceanography

University of California, San Diego
Scripps Institution of Oceanography
Ph.D. degree, March 1978
Major: Oceanography

B. POSITIONS HELD

Asst. Prof., Oceanography
University of Hawaii
March 1978 – June 1981

Assoc. Prof., Oceanography
University of Hawaii
July 1981 - June 1987

Professor, Oceanography
University of Hawaii
June 1987 – present

Director, Center for
Microbial Oceanography:
Research and Education
(C-MORE)
2006-present

C. HONORS AND AWARDS

Recipient, Presidential Young Investigator Award, White House and National Science Foundation, 1984 - 1989
Recipient, Board of Regents Excellence in Research Award, University of Hawaii (Junior Faculty) May 1985 and (Senior Faculty) May 1995
Recipient, G. Evelyn Hutchinson Medal, American Society for Limnology and Oceanography, June 1998
Elected, American Geophysical Union Fellow, February 1999
Recipient, A. G. Huntsman Medal, A. G. Huntsman Foundation and Bedford Institute of Oceanography, December 2001
Recipient, Gordon and Betty Moore Foundation Investigator in Marine Science Award, June 2004
Recipient, Henry Bryant Bigelow Medal, Woods Hole Oceanographic Institution, October 2004
Recipient, David Packard Distinguished Lecturer, Monterey Bay Aquarium Research Institute, November 2005
Elected to membership in the U.S. National Academy of Sciences, April 2006
Elected, American Society for Microbiology Fellow, April 2006

D. MEMBERSHIP IN PROFESSIONAL SOCIETIES

American Society of Limnology and Oceanography, American Society for Microbiology (and Hawaii branch), American Geophysical Union, National Society for Sigma Xi (and Hawaii branch), The Oceanography Society, Hawaii Academy of Science

E. PUBLICATIONS: David Karl has published nearly 300 scientific papers on various aspects of oceanography, ecology and environmental sciences. Selected recent publications include:

2002 KARL, D. M. Nutrient dynamics in the deep blue sea. *Trends in Microbiology* 10: 410-418.
2003 KARL, D. M., E. A. LAWS, P. MORRIS, P. J. leB. WILLIAMS and S. EMERSON. Metabolic balance of the open sea. *Nature **426:** 32*.
2004 DONEY, S. C., M. R. ABBOTT, J. J. CULLEN, D. M. KARL and L. ROTHSTEIN. From genes to ecosystems: the ocean's new frontier. *Frontiers in Ecology and the Environment **2:** 457-466*.
2005 DELONG, E. F. and D. M. KARL. Genomic perspectives in microbial oceanography. *Nature **437:** 336-342*.
2006 DELONG, E. F., C. M. PRESTON, T. MINCER, V. RICH, S. J. HALLAM, N.-U. FRIGAARD, A. MARTINEZ, M. B. SULLIVAN, R. EDWARDS, B. R. BRITO, S. W. CHISHOLM and D. M. KARL. Comparative genomics among stratified microbial assemblages in the ocean's interior. *Science **311:** 496-503.*
2006 HUISMAN, J., N. N. P. THI, D. M. KARL and B. SOMMEIJER. Reduced mixing generates oscillations and chaos in the deep chlorophyll maximum. *Nature **439:** 322-325*.
2007 BUESSELER, K. O., C. H. LAMBORG, P. W. BOYD, P. J. LAM, T. W. TRULL, R. R. BIDIGARE, J. K. B. BISHOP, K. L. CASCIOTTI, F. DEHAIRS, M. ELSKENS, M. HONDA, D. M. KARL, D. A.SIEGEL, M. W. SILVER, D. K. STEINBERG, J. VALDES, B. VAN MOOY and S. WILSON. Revisiting carbon flux through the ocean's twilight zone. *Science **316**: 567-570*.
2007 KARL, D. M. Microbial oceanography: paradigms, processes and promise. *Nature Reviews Microbiology **5:** 759-769.*
2008 KARL, D. M., L. BEVERSDORF, K. M. BJÖRKMAN, M. J. CHURCH, A. MARTINEZ and E. F. DeLONG. Aerobic production of methane in the sea. *Nature Geoscience **1:** 473-478*.
2008 CORNO, G., R. M. LETELIER, M. R. ABBOTT and D. M. KARL. Temporal and vertical variability in photosynthesis in the North Pacific Subtropical Gyre. *Limnology and Oceanography **53:** 1252-1265.*
2008 KARL, D. M. and R. M. LETELIER. Nitrogen fixation-enhanced carbon sequestration in low nitrate, low chlorophyll seascapes. *Marine Ecology Progress Series **364:** 257-268.*

F. SYNERGISTIC ACTIVITIES: (1) Development of database for education purposes: 13-year time-series data set from HOT program, available on CD-ROM and through Internet, (2) Member of several international and national planning committees for the future of ocean sciences, including the NSF Ocean Sciences Decade Plan, (3) Fellow of the American Geophysical Union, (4) Former member, NAS-Polar Research Board, (5) Member of the U.S. National Academy of Sciences, (6) Member of the Editorial Board of *Proceedings of the U.S. National Academy of Sciences* (*PNAS*), (7) Faculty of 1000, (7) Co-chair of *Ecology*

Roger Lukas

Professor of Oceanography
School of Ocean and Earth
Science and Technology
University of Hawaii at Manoa

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Education

Ph.D., Oceanography, 1981, University of Hawaii
M.S., Oceanography, 1977, University of Hawaii
A.B., Mathematics, 1973, University of Southern California

Employment

07/91—Present	Professor, Dept. of Oceanography, University of Hawaii
01/87—06/91	Associate Professor, Dept. of Oceanography, University of Hawaii
07/86—12/86	Associate Oceanographer, Hawaii Institute of Geophysics, U. of Hawaii
04/84—Present	Senior Fellow, Joint Institute for Marine and Atmospheric Research, U. of Hawaii
10/82—06/86	Assistant Oceanographer, Hawaii Institute of Geophysics, University of Hawaii
12/81—09/82	Visiting Scientist, Joint Institute for Marine and Atmospheric Research, U. of Hawaii
01/75—12/81	Graduate Research Assistant, University of Hawaii
09/74—01/75	Graduate Teaching Assistant, University of Hawaii
01/74—04/74	Laboratory Assistant, Woods Hole Oceanographic Institution

Five related publications

Dore, J.E., R. Lukas, D.W. Sadler, and D.M. Karl, 2003: Climate-driven changes to the atmospheric CO2 sink in the subtropical North Pacific Ocean. Nature, 424, 754 – 757, doi:10.1038/nature01885.

Finnigan, T.D., D.S. Luther and R. Lukas, 2002: Observations of enhanced diapycnal mixing near the Hawaiian Ridge. J. Phys. Oceanogr., 32, 2988-3002.

Letelier, R.M, D.M. Karl, M.R. Abbott, P. Flament, M. Freilich, R. Lukas and T. Strub, 2000: Role of late winter mesoscale events in the biogeochemical variability of the upper water column of the North Pacific Subtropical Gyre J. Geophys. Res. Vol. 105, No. C12, p. 28,723-28,740.

Lukas, R., 2001: Freshening of the Upper Thermocline in the North Pacific Subtropical Gyre Associated With Decadal Changes of Rainfall. Geophys. Res.Lett., 28, 3485-3488.

Lukas, R. and F. Santiago-Mandujano, 2001: Extreme Water Mass Anomaly Observed in the Hawaii Ocean Time-series. Geophys. Res. Lett., 28, 2931-2934.

Five other significant publications

Anderson, S.P., R.A. Weller, and R. Lukas, 1996: Surface buoyancy forcing and the mixed layer of the western Pacific warm pool: Observations and 1-D model results. J. Climate, 9, 3056-3085.

Feng, M., P. Hacker, R. Lukas, R. Weller and S.P. Anderson, 2000: Upper ocean heat and salt balances in the western equatorial Pacific in response to the intraseasonal oscillation during TOGA COARE. J. Climate, 13, 2409-2427.

Lukas, R., F. Santiago-Mandujano, F. Bingham and A. Mantyla, 2001: Cold bottom water events observed in the Hawaii Ocean time-series: Implications for vertical mixing. Deep-Sea Res. I, 48 (4), 995-1022.

Soloviev, A., and R. Lukas, 2006: ***The Near-Surface Layer of the Ocean***. Springer, 572 pp.

Weller, R.A., F. Bradley and R. Lukas, 2004: The interface or air-sea flux component of the TOGA Coupled Ocean–Atmosphere Response Experiment and its impact on subsequent air-sea interaction studies. J. Oceanic Atmos. Tech., **21**, 223-257.

Synergistic Activities

Climate Research Leadership: co-Chair, COARE Science Working Group; Co-chaired the US-Japan committee that led to the establishment of the International Pacific Research Center at U. Hawaii, and drafted its Science Plan; US CLIVAR Pacific Implementation Panel; NRC Climate Research Committee

Ocean Observing Leadership: co-leader, Hawaii Ocean Time-series; ALOHA Cabled Observatory co-PI; NAS Ocean Studies Board; Committee on Seafloor Observatories; Committee on Major Ocean Programs; Committee to Review the Ocean Research Priorities Plan; Hawaii regional coastal ocean observing system planning; OceanSITES Committee

Collaborators and other affiliations

M.R. Abbott (OSU), K. Ando (JAMSTEC), S.K. Behera (JAMSTEC), F. Bradley (CSIRO), F. Chai (UM), Y. Chao (JPL), S. Chen (U. Miami), S. Christensen, M. Church (UH), G. Corno (OSU), J. Dore (UM), F. Duennebier (UH), C. Fairall (NOAA), M. Feng (CSIRO), E. Firing (UH), A. Fong (UH), P. Hacker (UH), W. Han (CU), C. Hannides (Cyprus Inst.), T. Hasegawa (JAMSTEC), G. Holland (NCAR), A. Hu (NCAR), F.-F. Jin (UH), D. Karl (UH), A. Kohl (IFM),Y. Kushnir, M. Landry (SIO), J. Lean (NRL), R. Letelier (OSU), J.-J. Luo (JAMSTEC), M. McPhaden (NOAA), C. Mahaffey (U. Liverpool), Y. Masumoto (UT), V. Mehta (CRCES), M. Merrifield (UH), K. Mizuno (JAMSTEC), S. Park (UCSD), A. Plueddeman (WHOI), A. Proshutinsky (UAF), P. Schopf (GMU), U. Send (Kiel), A. Soloviev (Nova), D. Stammer (SIO), H. von Storch (Hamburg), P. Webster (G. Tech), R. Weller (WHOI), W. White (SIO), T. Yamagata (U. Tokyo), J. Zehr (UCSC), R. Zhang (JAMSTEC).

Students and Postdoctoral fellows supported and graduated

2008- , Rebecca Baltes, M.S. (advisor); 2006-2008, Kellee Nolan, M.S. (advisor); 2000-01, Tatsuo Suzuki, postdoc; 1998, Jim Potemra, Ph.D. (advisor); 1997, Ming Feng, Ph.D. (co-advisor); 1996-97, Bin Li, postdoc; 1992-94, Fred Bingham, postdoc; 1993, Toshiaki Shinoda, Ph.D. (advisor); 1993, Sean Kennan, M.S. (advisor); 1988-90, Steven Chiswell, postdoc; 1986, June Firing, M.S. (co-advisor); 1985, Ren-Chieh Lien, M.S. (co-advisor); Stewart Reid, Ph.D. 1994, 2 years support

Graduate and postdoctoral advisors

K. Wyrtki, E. Firing

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION: **University of Hawaii**				FOR NSF USE ONLY	
				PROPOSAL NO.	DURATION (months): Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Bruce M Howe**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Bruce M Howe - PI**	0.70	0.00	0.00	$ **10,792**	$
2. **Frederick K Duennebier - Co PI**	0.00	0.00	0.80	**10,874**	
3. **David M Karl - Co PI**	0.00	0.00	0.00	**0**	
4. **Roger Lukas - Co PI**	0.00	0.00	0.50	**9,460**	
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**4**) TOTAL SENIOR PERSONNEL (1 - 6)	0.70	0.00	1.30	**31,126**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**14**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	19.60	0.00	0.00	**125,037**	
3. (**1**) GRADUATE STUDENTS				**20,472**	
4. (**1**) UNDERGRADUATE STUDENTS				**10,236**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**186,871**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**45,437**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**232,308**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
12 bay RAID			$ **5,425**		
DSP&L camera and light system			**8,000**		
Thermistor string			**36,798**		
WetLabs FLNTU sensors, 2 each			**18,000**		
TOTAL EQUIPMENT				**68,223**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**8,966**	
2. FOREIGN				**6,160**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**45,778**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,500**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**22,750**	
TOTAL OTHER DIRECT COSTS				**71,028**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**386,685**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Cost (Rate: 38.4000, Base: 183983)**					
TOTAL INDIRECT COSTS (F&A)				**70,649**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**457,334**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **457,334**	$
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: **Bruce M Howe**	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: **Kathleen Yoshinaga**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 2

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of Hawaii

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Bruce M Howe

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Bruce M Howe - PI	1.00	0.00	0.00	$ 16,188	$
2. Frederick K Duennebier - Co PI	0.00	0.00	0.80	11,418	
3. David M Karl - Co PI	0.00	0.00	0.00	0	
4. Roger Lukas - Co PI	0.00	0.00	1.00	19,865	
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (4) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	1.80	47,471	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (12) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.70	0.00	0.00	65,101	
3. (1) GRADUATE STUDENTS				21,492	
4. (1) UNDERGRADUATE STUDENTS				10,746	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				144,810	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				29,836	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				174,646	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,741	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,500	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				75,800	
TOTAL OTHER DIRECT COSTS				81,800	
H. TOTAL DIRECT COSTS (A THROUGH G)				263,187	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Modified Total Direct Cost (Rate: 38.4000, Base: 247316)					
TOTAL INDIRECT COSTS (F&A)				94,969	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				358,156	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 358,156	$

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Bruce M Howe

ORG. REP. NAME*
Kathleen Yoshinaga

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Hawaii**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Bruce M Howe**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Bruce M Howe - PI**	1.70	0.00	0.00	$ **26,980**	$
2. **Frederick K Duennebier - Co PI**	0.00	0.00	1.60	**22,292**	
3. **David M Karl - Co PI**	0.00	0.00	0.00	**0**	
4. **Roger Lukas - Co PI**	0.00	0.00	1.50	**29,325**	
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**4**) TOTAL SENIOR PERSONNEL (1 - 6)	1.70	0.00	3.10	**78,597**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**26**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	28.30	0.00	0.00	**190,138**	
3. (**2**) GRADUATE STUDENTS				**41,964**	
4. (**2**) UNDERGRADUATE STUDENTS				**20,982**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**331,681**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**75,273**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**406,954**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **$ 68,223**					
TOTAL EQUIPMENT				**68,223**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**15,707**	
2. FOREIGN				**6,160**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**49,278**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**5,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**98,550**	
TOTAL OTHER DIRECT COSTS				**152,828**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**649,872**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**165,618**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**815,490**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **815,490**	$
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Bruce M Howe**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kathleen Yoshinaga**	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

Section A. Senior Personnel

Bruce Howe, PI, will provide overall project management and coordination and engineering direction, participate in the cruises, and analyze data. He moved to UH last year from the Applied Physics Laboratory, University of Washington (APL-UW), where he had been heavily involved in acoustical oceanography and cabled observatory and sensor network infrastructure development.

Roger Lukas, co-PI, will oversee the preparation and deployment of the TAAM component of the ACO, and he will work with other project personnel in developing, testing and implementing the real-time data management systems required. Lukas will work with the ACO Science and Technology Advisory Committee to help guide the further development of the ACO as a community resource. Lukas will also analyze existing and new data obtained through the ACO.

Fred Duennebier, co-PI, will support the PI, provide advice and direction regarding testing and deployment, participate in the cruise, and analyze data. He will be retiring September 2009 and changing status to emeritus professor, so this will be part-time work for him.

David Karl, co-PI, will be responsible for the bio-optical and video systems and data analysis with Howe, and providing coordination with C-MORE activities. His participation is at no cost to the project.

Section B. Other Personnel

Much of the engineering effort directly related to the node will be through the Engineering Support Facility (ESF). Harris (senior electrical engineer), Jolly (senior software engineer) and Babinec (senior electrical/software technician) have had extensive experience with scientific submarine cable systems, including HUGO, H2O, and now ACO. Heshiki (junior mechanical engineer) and Doi (group manager) have worked on the ACO project since inception. In addition, Howe is in the process of hiring engineering staff that will participate in this effort. The total engineering level of effort is 17 months.

Snyder will prepare the TAAM instrumentation and mooring for deployment, will direct its deployment, and participate in the ACO deployment.

Santiago-Mandujano and Lethaby will work with an assistant programmer to finish developing the data management components required for a fully operational ACO. These include real-time data communications, command and control interface, real-time data management, automated data processing, near-real time data services, and data archival. Santiago-Mandujano will work with Lukas for one month each year on data analysis. This activity will provide real tests of the data management components, and will result in feedback to the configuration of the data management system.

Morgan and Terada, project assistants, will provide support for project personnel, including procurement of equipment, materials and supplies, for cruise participation, and for travel arrangements.

Support for one undergraduate student and one graduate student working with Howe is included.

Section C. Fringe Benefits

The benefit and leave rates included in the budget are in accordance with UH's negotiated rates approved by the Department of Health and Human Services (DHHS) and UH policy on proposal budgets.

Section D. Equipment

Equipment valued at $33K is currently available for the TAAM, including components associated with the connection to the node (i.e., inductive modem, anchor frame and spool system and seafloor cable connecting the inductive modem to the observatory node) and an ADCP. Another $73K of equipment is presently deployed on a bottom-moored autonomous thermistor array at Station ALOHA, and is planned for recovery within the next year. With replacement of batteries and recalibration of sensors, this equipment is available for the TAAM component. One Sontek ADCP, damaged during the previous deployment effort, will be repaired or replaced; a pumped Seabird microcat (SBE-37P) with anti-fouling plugs; and an ROV wet mateable connector will be purchased ($37K). Two Wetlabs FLNTU chlorophyll fluorometer/turbidity sensors ($9K ea) and a DeepSea Power and Light color video camera and lights will be purchased ($8K). A RAID array ($5K) is needed to provide reliable mass storage for data management and archival. An existing RAID array will also be used for the project.

Section E. Travel

Seven domestic trips (nominally to the east coast) for Investigators and/or staff is budgeted to attend meetings (e.g., community ocean observatory science meetings, AGU, Oceans Sciences, workshops (e.g., the one planned by ODI for fall 2009). One trip to Australia is also budgeted for the Principal Investigator to attend IUGG (International Union of Geodesy and Geophysics) in 2011. Per diem rates used at specific locations are based on Federal allowable rates.

Section G. Other Direct Costs

Materials and Supplies

Instrument refurbishment includes batteries, calibration, and anti-foulant kits. Wire rope, an anchor, replacement glass balls, shackles and other hardware are required for the TAAM mooring. A port server is required for testing of instrumentation on the observatory. Also required for the ACO node work (associated with the ESF Effort table in Supplementary Documents) are electrical parts (Impulse Cable, 2 Impulse Connectors, Shunt Regulator, PCB manufacturing, Circuit board components), mechanical parts (2 Titanium endcaps, Sled Material, Chassis Plate, Modified Sled Material, Tooling), and other, totaling $49K.

Publications

For the three investigators collectively, $5K total is allocated for preparation, editing, and page charges of publications and presentations.

Other

The SOEST Research Computing Facility (RCF) charges $400/year per Internet connection; 7.5 connections are budgeted here.

Charges for use of the Hydrostat pressure facility and the Hurco numerically controlled machines total $12K.

The fixed annual operating costs (for year 2) includes $11K for the T1 line from the AT&T cable station at Makaha to UH, $30K for the Makaha shore station space lease, $1.3K for a RealAudio software license, and $26K for insurance.

Section I. Indirect costs

UH's negotiated indirect rate for federally sponsored on-campus research is 38.4% of Modified Total Direct Costs (MTDC). MTDC includes all direct costs less equipment, Research Computing Services, and the amount of sub-awards above the initial $25,000. Because part of the project is equipment fabrication, no indirect cost is charged to that portion. The equipment fabrication portion includes ESF salaries and benefits, supplies, and pressure/machine facility charges; the associated direct costs ($131,879 in year 1 and $13,271 in year 2 for a total of $145,150) are excluded from the base when calculating the indirect cost. The current Facilities and Administrative rate agreement with DHHS is dated 28 February 2006.

As per the Federal Demonstration Project, the UH may re-budget within the total estimated costs.

Current and Pending Support – Bruce M. Howe
April 27, 2009

Current Support

Bruce Howe moved from the Applied Physics Laboratory at the University of Washington (APL-UW) to the Department of Ocean and Resources Engineering at the University of Hawaii, as of 1 August 2008. The first four current awards below are subcontracts for continuing participation on existing grants at APL-UW.

The HOT Profiler: A Battery-Powered/Inductively-Charged, Satellite-Linked Moored Profiling System for Long Time Series of Rapid Vertical Profiles of Density and Velocity (Matthew Alford, PI, APL-UW; Bruce M. Howe, co-PI)
Source of Support: Ocean Technology & Interdisciplinary Coordination/NSF (Kandace Binkley, 703-292-7577, kbinkley@nsf.gov)
Total Award Amount: $1,129,913 (subcontract from APL-UW to UH for $30,748)
Total Award Period Covered: 08/01/07 - 07/31/10
Person-months per year: 0.85
Location of Project: University of Hawaii and Applied Physics Laboratory-University of Washington

Science and Technology Center for Coastal Margin Observation and Prediction (Antonio Baptistia, PI, OHSU; David Martin, co-PI, APL-UW; Bruce M. Howe, co-PI)
Source of Support: Ocean Technology & Interdisciplinary Coordination/NSF (Kandace Binkley, 703-292-7577, kbinkley@nsf.gov)
Total Award Amount: $10,997,000 (subcontract from APL-UW to UH for $68,093)
Total Award Period Covered: 07/01/06 - 06/30/11
Person-months per year: 0.8
Location of Project: University of Hawaii, Applied Physics Laboratory-University of Washington, and Oregon Health and Science University

A Smart Sensor Web for Ocean Observation: System Design, Modeling, and Optimization (Payman Arabshahi, PI, APL-UW; Bruce M. Howe, co-PI)
Source of Support: Advanced Information Systems Technology/NASA (Steven A. Smith, 301-286-7336, steven.a.smith@nasa.gov)
Total Award Amount: $1,496,226 (subcontract from APL-UW to UH for $34,000)
Total Award Period Covered: 09/05/06 - 09/04/09
Person-months per year: 0.8
Location of Project: University of Hawaii and Applied Phyiscs Laboratory-University of Washington

SENSORS: Collaborative Research: ALOHA Mooring Sensor Network and Adaptive Sampling (Bruce M. Howe, PI)
Source of Support: Ocean Technology & Interdisciplinary Coordination/NSF (Kandace Binkley, 703-292-7577, kbinkley@nsf.gov)
Total Award Amount: $2,659,977 (subcontract from APL-UW to UH for $5,948)
Total Award Period Covered: 10/01/03 - 09/30/09
Person-months per year: 0.2
Location of Project: University of Hawaii and Applied Physics Laboratory-University of Washington

Acoustic Seaglider: Planning for the Philippine Sea Experiment 2010-11 (Bruce M. Howe, PI)
Source of Support: Ocean Acoustics/ONR (Dr. Ellen Livingston, 703-696-4203, ellen.livingston@navy.mil)
Total Award Amount: $25,000
Total Award Period Covered: 09/01/08 - 09/30/09
Person-months per year: 0.25
Location of Project: University of Hawaii

Acoustic Seagliders: Mobile Tomography Receivers for the ONR Philippine Sea Experiment (Bruce M. Howe, PI)
Source of Support: DURIP/ONR (Dr. Ellen Livingston, 703-696-4203, ellen.livingston@navy.mil)
Total Award Amount: $360,000
Total Award Period Covered: 04/15/09 - 04/14/10
Person-months per year: 0.0
Location of Project: University of Hawaii

Pending Support

Characterization of New pH and pCO2 Sensors
Source of Support: National Science Foundation
Total Award Amount: $215,446
Total Award Period Covered: 4/2009-9/2010
Person-months per year: 0 person-months
Location of Project: University of Hawaii

Collaborative Research: Developing an Integrated Approach to Observing and Understanding the Feedback between Circulation and Tidal Mixing in Monterey Bay
Source of Support: National Science Foundation
Total Award Amount: $1,364,245
Total Award Period Covered: 07/01/2009 – 06/30/2012
Person-months per year: 0.5, 1, 1 person-months
Location of Project: University of Hawaii

ALOHA Cabled Observatory: Installation and Operation
Source of Support: National Science Foundation
Total Award Amount: $817,443
Total Award Period Covered: 07/01/2009 – 06/30/2011
Person-months per year: 0.7, 1 person-months
Location of Project: University of Hawaii

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include in this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Frederick K. Duennebier

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ * Transfer of Support

Project/Proposal Title: ALOHA Cabled Observatory (this proposal)

Source of Support: NSF

Total Award Amount: Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal.: 0.5 Acad: Sumr:

Support ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ * Transfer of Support

Project/Proposal Title: **ALOHA Cabled Observatory - Supplement**

Source of Support: NSF

Total Award Amount: $478,484 Total Award Period Covered: 1/1/07-6/30/09

Location of Project: SOEST, University of Hawaii at Manoa

Person-Months Per Year Committed to the Project. Cal.: 1 Acad: Sumr:

Support ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ * Transfer of Support

Project/Proposal Title:

Seismicity and 3-D velocity Structure of Loihi Submarine Volcano

Source of Support:

Total Award Amount: Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal.:1 Acad: Sumr: 1

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ * Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: Total Award Period Covered:

Location of Project: S

Person-Months Per Year Committed to the Project. Cal.: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ * Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal.: Acad: Sumr:

* If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Karl

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Collaborative research: Hawaii Ocean Time-series: Biogeochemistry and ecology component

Source of Support: NSF

Total Award Amount: $ 5,332,083 Total Award Period Covered: 08/01/03 - 07/31/09

Location of Project: University of Hawaii and Hawaiian waters

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 1.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Contemporary challenges in microbial oceanography

Source of Support: The Agouron Institute

Total Award Amount: $ 2,671,279 Total Award Period Covered: 03/01/06 - 02/28/10

Location of Project: University of Hawaii

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Center for Microbial Oceanography: Research and Education (C-MORE)

Source of Support: NSF

Total Award Amount: $ 18,960,000 Total Award Period Covered: 08/01/06 - 07/31/11

Location of Project: UH, MIT, MBARI, OSU, UCSC, WHOI

Person-Months Per Year Committed to the Project. Cal:6.00 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Equipment for Ocean Science Facility

Source of Support: Gordon and Betty Moore Foundation

Total Award Amount: $ 1,995,400 Total Award Period Covered: 11/15/07 - 12/15/09

Location of Project: University of Hawaii

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Sumr: 0.00

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: Moore Foundation Award: 2008-2012

Source of Support: Gordon and Betty Moore Foundation

Total Award Amount: $ 3,796,946 Total Award Period Covered: 05/15/08 - 05/14/12

Location of Project: University of Hawaii

Person-Months Per Year Committed to the Project. Cal:0.00 Acad: 0.00 Summ: 1.00

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

 USE ADDITIONAL SHEETS AS NECESSARY

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: David Karl

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: The Hawaii Ocean Time-series (HOT): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre (Matt Church, P.I.)

Source of Support: NSF

Total Award Amount: $ 6,123,580 Total Award Period Covered: 08/01/09 - 07/31/13

Location of Project: University of Hawaii and Hawaiian waters

Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: ALOHA Cabled Observatory (Bruce Howe, P.I.)

Source of Support: NSF

Total Award Amount: $ 873,930 Total Award Period Covered: 07/01/09 - 06/30/11

Location of Project: University of Hawaii and Hawaiian waters

Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: 0.00 Sumr: 0.00

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support – Roger Lukas
April 21, 2009

Current Support

ALOHA Cabled Observatory - Supplement (Fred Duennebier PI)
Source of Support: NSF OCE 06-52430
Total Award Amount: $478,484
Total Award Period Covered: 03/15/07 – 08/31/09
Person-months per year: 0.0
Location of Project: University of Hawaii

Hawai‘i Ocean Time-series: Study of Subtropical Gyre Physics and Climate Interactions (Roger Lukas PI)
Source of Support: NSF OCE 07-52606
Total Award Amount: $772,175
Total Award Period Covered: 09/01/08 – 02/28/10
Person-months per year: 1.0 (summer)
Location of Project: University of Hawaii

SENSORS: Collaborative Research: ALOHA Mooring Sensor Network and Adaptive Sampling (Roger Lukas, PI)
Source of Support: NSF OCE 03-30294
Total Award Amount: $229,731
Total Award Period Covered: 10/01/03 – 07/31/09
Person-months per year: 0.5 (academic) and 0.5 (summer)
Location of Project: University of Hawaii

A Time-Series Study of Ocean Climate Processes in the North Pacific Subtropical Gyre (Roger Lukas, PI)
Source of Support: NSF OCE 03-27513
Total Award Amount: $2,829,554
Total Award Period Covered: 10/01/03 – 09/30/09
Person-months per year: 2.0 (academic) and 1.0 (summer)
Location of Project: University of Hawaii

Pending Support

Characterization of New pH and pCO2 Sensors
Source of Support: National Science Foundation
Total Award Amount: $215,446
Total Award Period Covered: 4/2009-9/2010
Person-months per year: 0 person-months
Location of Project: University of Hawaii

Collaborative Research: Developing an Integrated Approach to Observing and Understanding the Feedback between Circulation and Tidal Mixing in Monterey Bay
Source of Support: National Science Foundation
Total Award Amount: $1,364,244
Total Award Period Covered: 07/01/2009 – 06/30/2012
Person-months per year: 0.25 summer months per year
Location of Project: University of Hawaii

The Hawaii Ocean Time-series (HOT): Sustaining ocean ecosystem and climate observations in the North Pacific Subtropical Gyre
Source of Support: National Science Foundation
Total Award Amount: $6,201,876
Total Award Period Covered: 08/01/2009-07/31/2013
Person-months per year: 1.00 summer months per year
Location of Project: University of Hawaii

ALOHA Cabled Observatory: Installation and Operation
Source of Support: National Science Foundation
Total Award Amount: $873,930
Total Award Period Covered: 07/01/2009-06/30/2011
Person-months per year: 0.50, 1.00 summer months per year
Location of Project: University of Hawaii

Facilities, Equipment, and Other Resources

University of Hawaii
School of Ocean and Earth Science and Technology

Engineering Support Facility

SOEST provides an Engineering Support Facility (ESF) for its scientists and researchers. ESF has experience going back over 35 years in custom modifications and enhancements to existing instruments, as well as the repair and maintenance of laboratory instruments and equipment. There are two senior electrical engineers, a senior mechanical engineer, two electronics technicians, a machinist, and a shop assistant. Facilities include computers, large-format printers, CAD software, offices, staging areas, electronics shops, and a fully equipped machine shop, with storage for various electronics parts, construction materials, and time-sensitive deployment systems.

In experiment system integration, ESF can provide microcontroller-based systems for integrating all of the components of an experiment. ESF has extensive experience with a variety of sensors and transducers. ESF can provide custom Analog-to-Digital converters up to 24-bit resolution. Besides the design of electronic circuits, the ESF provides printed circuit board layout and outsourced PCB production, assembly and testing of printed circuits and integration into the finished experiment. The ESF has a well-equipped machine shop and an expert instrument maker, as well as Pressure Test Facilities. ESF operates a hydraulic pressure test vessel that can test pressure cases from 15 to 10,000 psia, with electronic feed-thru capability. The test vessel can accommodate objects up to 30 inches in outside diameter by 13 feet length.

The facility is being reorganized to more effectively serve the needs of the SOEST community, with the main functions and infrastructure being available to support the present proposal.

Computing Facilities

Investigators in the School of Ocean and Earth Science and Technology at the University of Hawaii have access to several compute platforms. Individual workstations are maintained by the School's Research Computer Facility (RCF) and each Investigator has access to at least one. Finally, each Investigator has access to a wide array of computing platforms available through their respective departments and/or units within the school.

Supplementary Documents

Letter from Ocean Design, Inc., 3 March 2009

ALOHA Cabled Observatory Phase 2 Installation Cruise Report, 2 November 2008

Ocean Design Cable and Connector Failure Report, 6 March 2009

Ship request form

ALOHA Cabled Observatory (ACO): Management Plan for Long-term Operations

Letter from J. Oswald and T. Norris

Letter from K. Smith

Letter from J. Drazen and C. Smith

ODI
A Teledyne Majority Owned Compan

1026 North Williamson Boulevard
Daytona Beach, Florida 32114 USA
P: 386.236.0780 F: 386.236.0906
Toll Free: 1.888.506.2326
www.odi.com

March 3, 2009

Dear Fred,

Ocean Design, Inc. takes great pride in the quality and reliability of its products, and we were very disappointed to learn that the ALOHA Cabled Observatory installation in October 2008 failed, reportedly because of problems with connectors manufactured by our company. We are in the process of reviewing the failures encountered and will release a full report detailing our evaluation and findings. It is our intent to provide fit-for-purpose replacements for any failed items regardless of any warranty position. It is rare for ODI to receive equipment back for reasons of failure due to manufacturing defects. We have nearly 100,000 units deployed with relatively few returns for manufacturing/design defects.

These assemblies were shipped in 2005. ODI seeks constant improvement in all areas of our processes. Since shipping these assemblies, our assembly and in-process test and quality processes have evolved significantly. Additional, in-process test points and screening operations are built into the process so that each connector component of the assembly is rigorously leak tested independently and then pressure tested again as a complete assembly.

We are aware that we must take additional steps in documenting additional safe handling and installation procedures for our equipment in order to mitigate the possibility of reoccurrence in the future. We recognize that more training in the design, deployment and operation of our products will be advantageous to many of our customers.

We thus will work closely with you and your colleagues at the University of Hawaii in analysis of the problems encountered and will be involved with testing and installation of the observatory, including having a field technician on the cruise to offer guidance and assistance.

Any solutions to the problems encountered will also benefit future installations, particularly those utilizing optical fiber connectors in deep ocean applications. To that end, ODI proposes hosting a meeting here at our Daytona Beach Headquarters in the fall of 2009, for a review of issues encountered in the Aloha Program deployment and to explore the aforementioned evolutionary enhancements to assembly, test and quality processes that will assure success in future deployments for all observatory projects. I would suggest that among the invitees will be appropriate engineers and program officers of ocean observatory projects such as: ACO, NEPTUNE Canada, OOI/RSN, DONET, ESONET.

Our aim is to provide the marine community with reliable products. Opportunities to improve our product line by working with experienced customers, such as your team, significantly aids in this effort.

Regards,

John Flynn
Vice President Sales & Marketing

ALOHA CABLED OBSERVATORY

PHASE 2 Installation Cruise Report

Fred Duennebier

David Harris

James Jolly

November 2, 2008

Rev. 2

Summary:

The purpose of cruise TGT 226, was to install the 2nd phase of the ALOHA Cabled Observatory (ACO) using the JASON-2 ROV to plug in the observatory and associated experiments. A secondary project, time permitting, was to collect rocks and perform bottom surveys in selected areas of the Ka'ena Ridge.

Installation of the Observatory during this cruise was not possible because of the failure of cables and connectors supplied by Ocean Design, Inc.

Background

Installation of the ACO was divided into two phases. The first phase cut, moved and terminated the HAW-4 electro-optical cable at Station ALOHA, and lowered it to the ocean floor with a set of preliminary experiments (the Proof Module). Phase 1 was accomplished in February, 2007, by the USNS ZEUS. Real-time hydrophone and pressure data had been flowing continuously through the cable since that time. Phase 2 of the ACO, originally scheduled for November, 2007, was to use JASON-2 to install the main observatory. That operation was delayed for a year as a result of late delivery of defective pressure vessels.

The technology to plug in electrical and optical systems on the ocean floor has made it possible to consider building general-purpose observatories in the deep ocean. Ocean Design, Inc. (ODI, http://www.odi.com/) is the only ocean cable provider for suitable submarine wet-mate electrical and optical cables and connectors. Their cables were used in HUGO, H2O, ACO, and other observatories. Cables and connectors supplied to ACO by ODI have cost the project more than $200,000 (See Attachment A). Cabling for Phase 2 is shown in Figure 1.

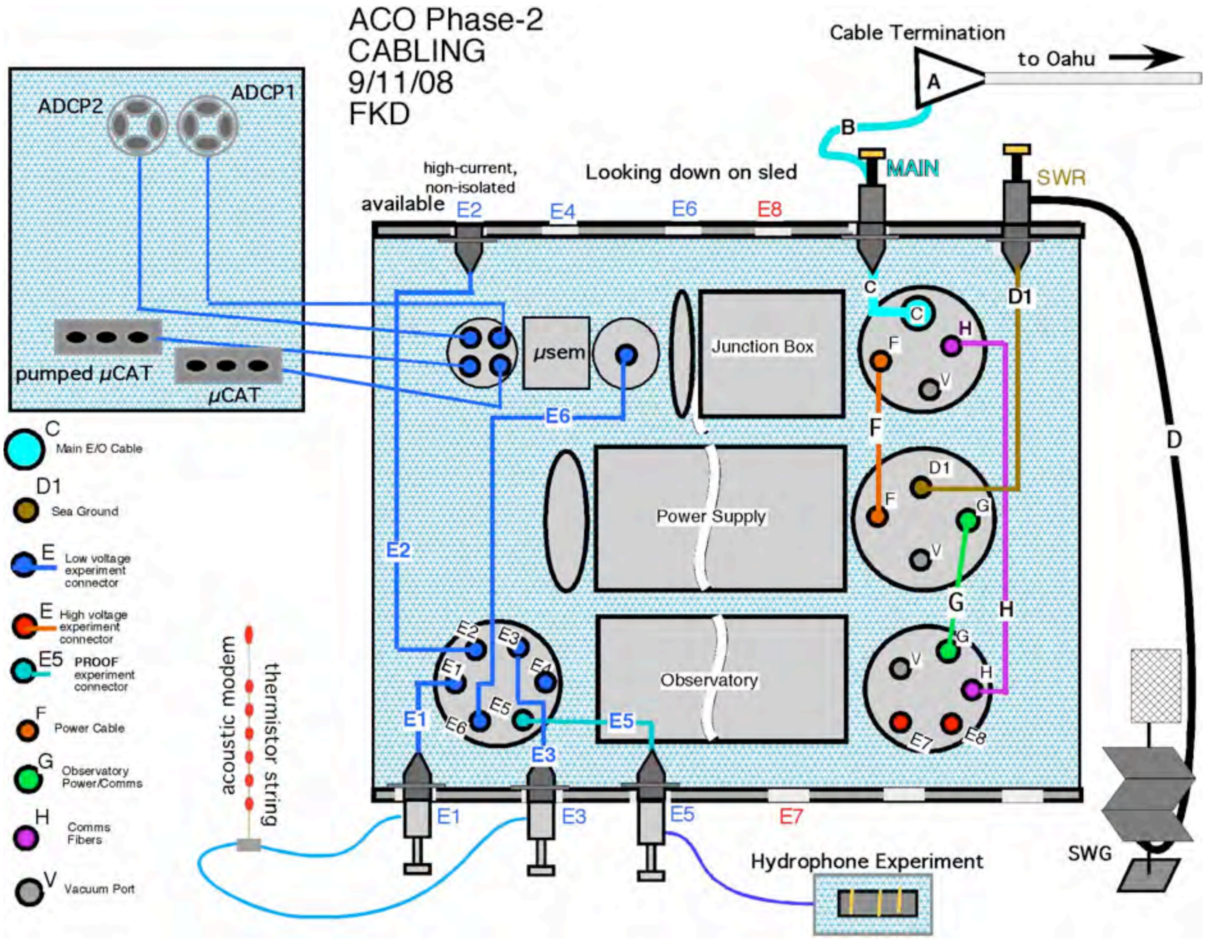

Figure 1. ACO Phase 2 Cabling and Sensors. Cable assemblies, including cables and connectors and/or feed-throughs, A, B, C, D, D1, E, F, G, and H, and the Proof Module umbilical, B1, (not shown) were supplied by ODI.

Cables to experiments (E) were heavily modified by the SOEST ESF in 2007 to improve their mechanical characteristics and to operate better when using Ethernet signals. Cable assemblies A, B, C, H, and the Proof Module umbilical contain optical fibers.

Prior to sailing on the October, 2008 cruise, the system had been operated successfully for more than a year without significant problems. All cabling had been tested before Phase 1 through Cable A before it was spliced into the main cable. All fibers except fiber 2 in cable "H" showed normal attenuations at that time. Fiber 2 in cable H, which showed excessive attenuation, was not used in the final configuration.

A test system consisting of a version of the shore station electronics used at the Makaha Cable Station, where the cable comes to shore on Oahu, was used during testing both on shore and at sea. The only significant differences between installed operation and test operation were the optical attenuation required to prevent saturation of the optical amplifiers, and the bypassing of cables C and B (Figure 1) which could not be tested because of the lack of an adequate test cable and connector.

The test cable necessary for end-to-end system testing through cables B and C was not supplied by ODI until a week before the cruise. Negotiations concerning this test cable were long and frustrating. Initially ODI wanted to charge more than $37,000 for purchase of the cable (which would only be used for testing). An alternative was then suggested where we would lease the cable for more than $5,000 per week. Eventually, ODI agreed to loan the cable at no cost if we then allowed them to have our ACO Phase 1 umbilical cable after we were done with it, with the option to use it again when needed. The test cable was finally received from ODI about 1 week prior to the cruise. Rather than the cable specified containing four fibers and two electrical connections, however, it was immediately recognized that the delivered cable contained four electrical connections and two fibers, rendering it incompatible for connection to cable C (ODI part # ___), and useless.

CRUISE NARRATIVE:

10/18/08 The cruise was delayed and shortened by one day so that the chief mate on the Thompson could be replaced at the last minute due to illness. The ACO system was set up the staging bay and tested, showing nominal operation.
10/19/08 After deploying long-baseline navigation transponders, the first JASON-2 dive, J2-376, located the cable termination roughly 150 m from the anticipated location. The cable termination and Proof Module appeared as expected, with the Proof Module floating above the cable termination and considerable white deposits covering the Proof Module sea water return (Figure 2).

The region within 100 m of the cable termination was surveyed on 10 m lines and clear quadrants to the NE, NW, and SW from the termination were found suitable for experiments.

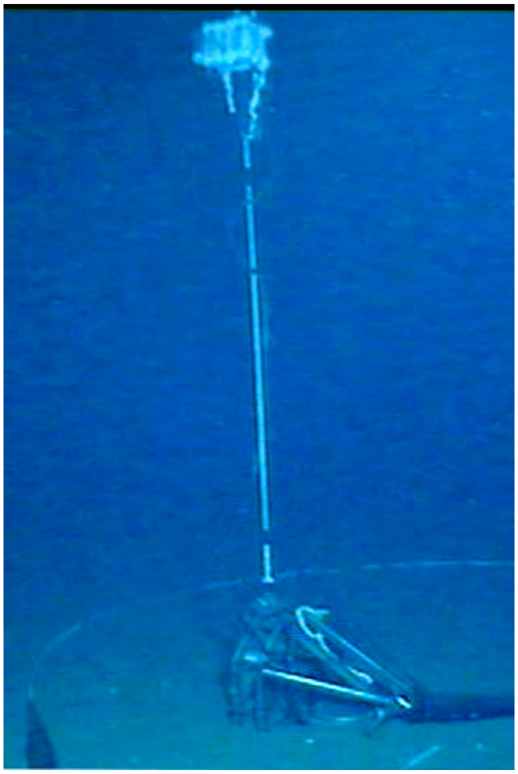

Figure 2. Proof Module suspended above the cable termination. The Proof Module float package is out of sight above. [JASON-2 image frame grab].

10/20/08 JASON was recovered from the first dive and the observatory was lowered to the bottom on the 9/16” trawl wire together with a navigation transponder, acoustic release, and a pinger for bottom detection. The navigation transponder imploded as the package approached the bottom, and the package was returned to the surface (but not recovered to the deck). The transponder was replaced and the package lowered again. The Edge Tech acoustic release failed to release on this lowering, and the package was again returned to the surface and the release was replaced with a Benthos release. On the 3rd lowering, the release was triggered after many attempts, and the package settled to the bottom only 2 m closer to the cable termination than planned, an accuracy of 0.04% of the water depth, an excellent feat of navigation and ship control (Figure 3). Note that the ACO sled had been cycled to 4700 three times at this point.

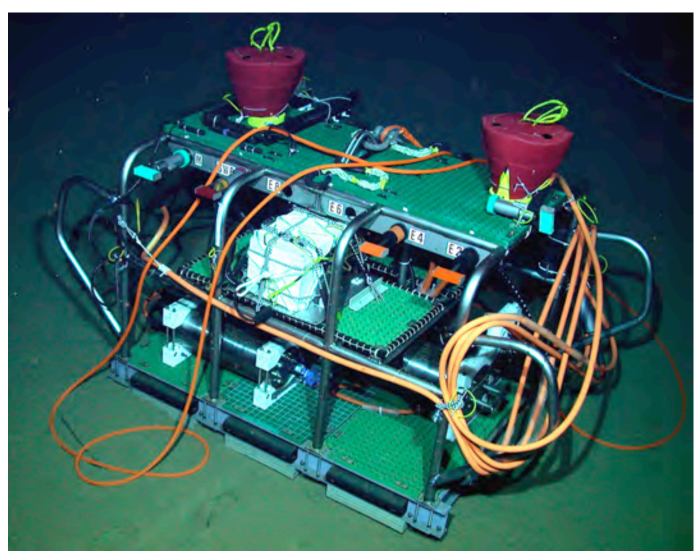

Figure 3. ACO sled on bottom sfter lowering. The two red “hats” protect the two ADCPs. [JASON-2 still digital image.]

10/22/08 On the 2nd JASON dive (J2-377), the cable power was turned off at Makaha and the Proof Module was unplugged from the cable termination. The connector was moved to the holster on the Proof Module where a stream of oil bubbles was visible coming from the Proof Module umbilical connector, indicating that the cable was leaking oil (Figure 4).

The main umbilical (Cable B in Figure 1) was very difficult to plug in. The connector was finally connected after more than an hour of trying, including tipping the cable termination on it's side at one point. Similar problems had been observed with this cable while plugging it in during testing in the lab, and ODI was contacted concerning the problem, but offered no advice. It was found that the connector would sometimes connect with little difficulty and at other times not be connectable with more than 100 lbs of force.

Figure 4. Proof Module Umbilical in the holster on the Proof Module. A stream of oil bubbles can be seen rising from the right side of the connector. [Jason-2 frame grab.]

After connection was finally made, the cable power was restored and the system tested by Jim Jolly and Jim Babinec at the Makaha Cable Station. They reported that while cable power drain was as expected, there was no communication with over the optical data link. The clock pulse generated in the JBox was present, however, indicating that there was communication with the JBox, but not to the Observatory. After more testing and discussions with Mark Tremblay in New Jersey (one of the AT&T designers of the original cable system and instrumental in the design of the optical communications used by ACO), it was determined that the ACO must be brought back on board so that optical levels could be tested.

We also decided that the Proof Module should be returned to the surface so that it's umbilical could be used in the testing in lieu of the test connector that was to have been provided by ODI. JASON cut the rope to the Proof Module using their "hedge clipper", and it surfaced about 100 m from the ship 95 minutes later. JASON was recovered at 03:00 UT on 10/23/08.

10/23/08 16:40 UT. JASON and Medea were rigged for recovery of the ACO and sent to the bottom (Dive 3, J2-378). The "Sky Hook" was dropped from Medea and connected into one of the recovery ropes on the ACO sled. About 2000 m from the surface, the ACO sled dropped off in large swell with signs of snap loading in the wire tension. When recovered, the recovery rope had parted at a poorly-made splice (made by Duennebier). JASON was again rigged for recovery of the sled and sent to the bottom (Dive 4, J2-379, 10/24/08 06:00 UT) to run a search grid. Luckily, the sled was located (on it's side) within 1.5 hours after reaching the bottom and returned to the surface without further incident. The dive ended at 10/24/08 14:00 UT. There was likely damage to one of the ADCPs, minor damage to one of the micro-Cats, and one of the ADCP covers was missing, but all else appeared normal.

Initial testing of the recovered ACO sled on deck (through the Proof Module umbilical plugged into "C" in Figure 1) showed the same symptoms as were observed at Makaha, i.e. proper electrical power draw and clock, but no communications between the test setup (called "mini-Makaha) and the Observatory going. Between 1/2 and 1 cup of oil was found in the Proof Module indicating that the high-pressure seal in the Proof Module umbilical connector (B1) had at least partially failed.

The situation changed rapidly, and it was soon impossible to power the system through the Proof Module umbilical, with the electrical power draw indicating a partial short circuit. While testing on deck, Duennebier received an electric shock while touching the ship and the Proof Module umbilical connector. This should not have happened, and it was determined that there was a partial short between the Proof Module connector and the power conductor, indicating salt incursion into the oil-filled cable. The JBox was removed from the ACO sled and opened. It was found to be dry and normal. The Proof Module umbilical and main observatory umbilical were bypassed by opening the JBox pressure vessel and powering the system directly into the JBox. This restored the correct power draw, indicating an electrical fault in the B1 cabling, but we still could not communicate between the JBox to the Observatory module to control the observatory power supply and experiment ports.

By this time it was obvious that we were dealing with serious problems, far more serious than incorrect optical attenuations. It was decided to move the observatory back into the staging bay and do a rock dive with JASON on Ka'ena ridge while the system was evaluated (Dive 5, J2-280 begun 10/25/08 17:00 UT).

The ODI multi-mode 4-fiber dry-mate optical cable (H in Figure 1) between the observatory and the JBox had showed heavy attenuation with one fiber (2) in early lab testing, but that fiber was not used. Testing of the remaining fibers showed new high attenuations that explained the lack of communication between the Observatory and the JBox. This cable had been operating normally during on-board testing before deployment and it had not been disconnected since weeks before the cruise. Observation of the male connector on the JBox shows that the fibers extend to different lengths, indicating that the attenuation may be caused by lack of contact. Testing of the fibers in this cable indicates that the attenuation in the cable itself is negligible, thus the problem appears to be in the JBox connector and possibly in the connector on the end connected to the Observatory pressure vessel. The failure of cable H after deployment was directly responsible for the system failure.

It was now obvious that the problems with the cabling made it unreasonable to install the observatory, and it was decided to make some changes to the Proof Module and reinstall it. Changes included changing the data format from Manchester encoding to Ethernet and adding a high-frequency hydrophone. The Proof umbilical also needed to be drained of oil, cleaned, and re-filled with oil. While this would not repair the Proof Module umbilical, it was hoped that it might survive long enough to provide valuable data.

While Harris, Howe, Duennebier, and later Snyder worked on the conversions of the Proof Module, the thermistor array was rigged for autonomous deployment at Station ALOHA, rather than as an ACO experiment (See TAAM cruise report). In this configuration, the thermistor array will collect near-bottom temperature values for about two years or until it's acoustic release is triggered and it is recovered during a HOT cruise. The thermistor array was rigged and deployed without incident.

Leakage resistance values of about 5 KOhms were observed between the connector and the power conductor in the Proof umbilical. Nominal resistance should be infinite. After draining the oil from the Proof umbilical cable, alcohol was used to clean the connectors inside the cable and the cable was dried with helium. After cleaning, resistance was too high to measure as expected, and the cable was refilled with mineral oil supplied by the JASON team.

While the Proof Module and Thermistor array preparations were underway, JASON Dive 6 (J2-381, 10/27/08 15:00 UT) was made for more rocks at Ka'ena Ridge and to visualize the bottom roughness in the area where a mooring had been placed by Jerome Aucan. Both rock dives were very successful.

After two 16-hour days of work by Dave Harris, Bruce Howe, Jefrey Snyder, and Duennebier, the Proof Module was ready to drop over the side for plug-in by JASON at 0800 on October 28, 2008. At this time the JASON team asked for an hour hold for weather, with winds increasing and heavy swell - by far the worst weather we had seen. After an hour we were informed that JASON would not be able to dive, and weather was not predicted to improve for several days. We thus left the site and headed for Honolulu, docking at 08:00 HST on 10/28/08.

Failure summary:

Test Connector: The failure to provide the correct test connector required us to return the Proof Module to the surface to use it's umbilical as a test connector for testing of the system. Had we not been required to recover the Proof Module, we would likely still be collecting ACO Proof Data.

Proof Umbilical (Cable B1): This cable system connects the cable termination to the Proof Module. The high-pressure seals in the Proof umbilical failed, allowing oil to enter the Proof Module feed-through end, and to leak oil from the other (wet mate connector) end. When brought to the surface, salt water had entered the cable partly shorting out the connector.

Cable “H” multi-mode fiber whip: This cable system provides communications between the JBox and the Observatory. The optical attenuation in the optical path increased beyond what was necessary to support communication between the JBox and the Observatory. Failure of this cable and its connectors was responsible for the failure to install the ACO.

In addition, cable B may also have failed, although we have not tested it independently. It is certainly suspect, as it has the same design as the Proof Umbilical Connector.

In testing to date, we have found absolutely no problems with the electronics and optical systems except for the ODI cables and connectors, and we do not know of any tests we could have performed prior to the cruise that would have detected these faults. These failures have cost far more than the value of these cables, as the costs of the cruise were essentially wasted and delay of at least one year is inevitable before resuming operations and completing the ACO.

Attachment A

- Quotation #7531 Rev. C -

Ocean Design is pleased to offer the following quotation:

Date: July 26, 2005

To: University of Hawaii

Attn: Dave Copson

Re: ALOHA RFQ

The following pricing includes Ocean Design's standard Factory Acceptance Testing (FAT) in accordance with our latest FAT procedures.

				Conn/Assy Qtys		Customer	
	No. of Cust Line	Unit	ODI Assembly Part Number (Type Designation)	Qty Per Line	TOTAL	Line Item Unit	Line Item Total
Item	Items	Rated for 2.3kVAC @ 30A, 4800 Meters		Item	QTY	Price	Price
1	1	**Cable Umbilical Termination - A**	TBD	1	1	$53,971	$53,971
1.1	1	Hybrid Whip		1	1		
1.2	1	1 In / 1 Out (2E / 4SMFO) Field Installable Testable Assembly (FITA) Termination - Titanium Shell		1	1		
1.3	1	4 Meter x 2E / 4SMFO ODI Oil Filled Hose		1	1		
1.4	1	2E / 4SMFO Bulkhead ROV NRH Plug (Sockets) with Straight Hose Termination - Titanium Shell		1	1		
2	1	**Proof Module - B1**	TBD	1	1	$27,159	$27,159
2.1	1	2E / 4SMFO Cable End ROV NRH Receptacle (Pins) with Right Angle Hose Termination - Titanium Shell		1	1		
2.2	1	10 Meter x 2E / 4SMFO ODI Oil Filled Hose		1	1		
2.3	1	2E / 4SMFO Cable End Penetrator with Straight Hose Termination - Titanium Shell		1	1		
3	1	**Main Umbilical - B**	TBD	1	1	$41,169	$41,169
3.1	1	2E / 4SMFO Cable End ROV NRH Receptacle (Pins) with Right Angle Hose Termination - Titanium Shell		2	2		
3.2	1	10 Meter x 2E / 4SMFO ODI Oil Filled Hose		2	2		
3.3	1	In-Line Fiber Management Canister - Titanium Cp, Gr2 Shell		1	1		
4	1	**Main Whip - C**	TBD	1	1	$25,944	$25,944

4.1	1	**2E / 4SMFO Bulkhead ROV NRH Plug (Sockets) with Straight Hose Termination - Titanium Shell**		1	1		
4.2	1	**3 Meter x 2E / 4SMFO ODI Oil Filled Hose**		1	1		
4.3	1	**2E / 4SMFO Cable End Penetrator with Straight Hose Termination - Titanium Shell**		1	1		
5	1	**Sea Ground - D**	**TBD**	1	1	$5,602	$5,602
5.1	1	**4E (2 Used) Cable End ROV Plug (Pins) with Right Angle Molded Termination -** Titanium Shell		1	1		
5.2	1	10 Meter x 2E Polyurethane Jacketed Cable (CSM)		1	1		
6	1	**Sea Ground Whip - D1**	**TBD**	1	1	$3,732	$3,732
6.1	1	4E (2 Used) Bulkhead ROV Receptacle (Sockets) with Straight Molded Termination - Titanium Shell		1	1		
6.2	1	3 Meter x 2E Polyurethane Jacketed Cable Molded to Connector (CSM)		1	1		
7	4	**Experiment Whips - E**	**TBD**	1	4	$3,713	$14,852
7.1	4	12E Bulkhead ROV Receptacle (Sockets) with Straight Molded Termination - Titanium Shell		1	4		
7.2	4	3 Meter x 12E Cable with Polyurethane Jacket Molded to Impulse Connector **(CSM)**		1	4		
8	1	**Experiment Test Connector - E1**	**TBD**	1	1	$3,950	$3,950
8.1	1	12E Cable End ROV Plug (Pins) with Straight Molded Termination - Plastic Shell		1	1		
8.2	1	3 Meter x 12E Cable with Polyurethane Jacket **(CSM)**		1	1		
9	1	**Optical Harness - H**	**TBD**	1	1	$10,862	$10,862
9.1	1	4SMFO Cable End Submersible Connector with Straight Hose Termination - Titanium Shell		2	2		
9.2	1	3 Meter x 4SMFO ODI Oil Filled Hose		1	1		
		Optical Bulkhead - H	**TBD**				
10	2	4SMFO Bulkhead Submersible Connector with Pigtails - Titanium Shell		1	2	$3,486	$6,972
		NRH Marine Growth Cover					
11	1	**Protective Cap** for 2E / 4SMFO Bulkhead ROV NRH Plug (Sockets) - Plastic Shell	**1007142 FHT-076-01**	1	1	$640	$640
		NRH Parking Position					
12	1	**Protective Cap** for 2E / 4SMFO Cable End ROV NRH Receptacle (Pins) - Titanium Shell	**1029079 NRH-054-01**	1	1	$6,514	$6,514

		12E Marine Growth Cover					
13	1	**Protective Cap** for 12E Bulkhead ROV Receptacle - Plastic Shell	**1014022 ROV-159-01-1**	1	1	$609	$609
	1	Totals					$201,976

Delivery	Electrical Assemblies 8 Weeks After Approval of Engineering Drawings. Optical Assemblies 14 Weeks After Approval of Engineering Drawings. Drawings Delivered 4 Weeks ARO. Customer Supplied Material Required 4 Weeks Prior to Shipment.
Point of Delivery	FOB Ocean Design Inc, Ormond Beach, Florida
Payment Terms	Discount 1%-10, Net 30 Days From Date of Invoice

Price includes Certificate of Conformity. Standard QC documentation is provided in electronic format. Paper copies are subject to an additional charge.

Customer Witness/Third Party Inspection may be subject to an additional delivery time and charges at time of order. Please contact ODI for information.

This Quotation, valid for 30 days, is subject to Ocean Design, Inc. Standard Terms and Conditions of Sale/Rev B - dated 01-May-2004 - that are available on request or from the Sales and Service page of our website at www.odi.com.

Sincerely,
For Ocean Design, Inc.

Christopher McPherson

Ocean Design Cable and Connector Failure Report
F. Duennebier, David Harris
March 6, 2009

Summary: Duennebier and Harris visited ODI in Daytona Beach, FL on February 23-24, 2009 to take part in testing and dismantling connectors and cables that failed during the October, 2008 ACO cruise. Six cable system failure modes were identified, including the failure that resulted in failure of installation of the ACO Phase-2 system. While leakage paths of oil into the connectors and feed-thrus were not obvious, they certainly did exist, and new testing and qualification procedures at ODI should minimize such failures in the future. Changes to be made in the ACO system will minimize the use of optical connectors in the Observatory system.

ODI management, engineers, and technicians were very cooperative in testing and providing support. They have agreed to supply an appropriate letter of support for inclusion with the proposal, to supply all cable systems we require for re-installation at no-cost, and to provide technical support on the installation cruise.

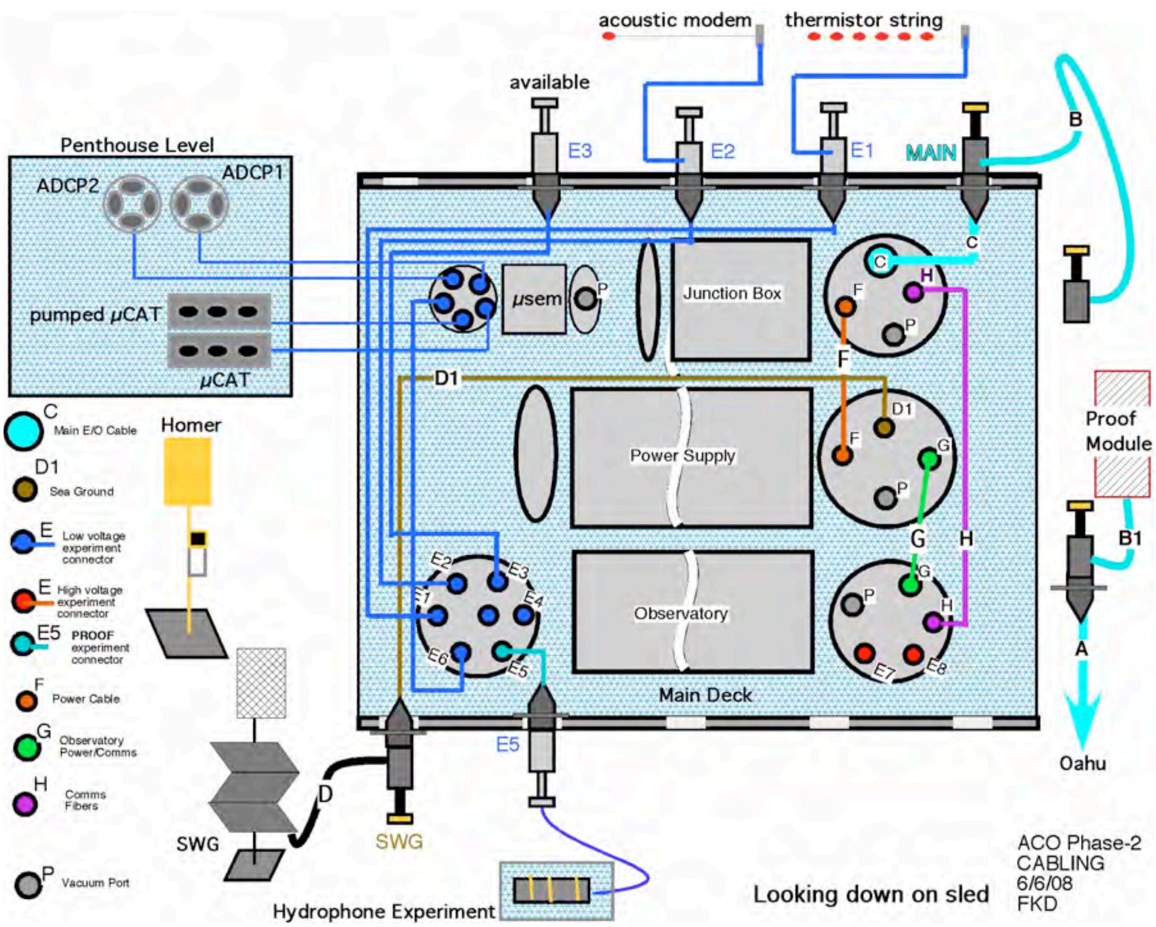

Figure 1. Cartoon of cabling as it existed during the October, 2008 ACO cruise.

ACO Cable system status.

A: Wet-mate hybrid bulkhead NRH in cable termination. Condition: Some **difficulty connecting** on Phase-2 cruise, but last connection was OK. See discussion.

B1: Connected Cable termination (A) to Proof Module. This cable operated at the Observatory for 20 months. Flying NRH hybrid on A-end has a **failed pressure seal** that leaked oil into the water on bottom and allowed water to enter the cable when brought to the surface. Oil leak site could not be determined in testing. **Secondary water seal on electrical contacts failed** during subsequent use of this connector for testing on the ship, causing burned insulation and shorting to the connector housing. The Proof-Module end **pressure seal failed**, leaking about ½ cup of oil into the Proof Module. Dissection at ODI shows that oil leak was likely in the optical feed-thru.

B: Connects cable termination to observatory sled. NRH hybrid flying connectors on both ends. **Difficult to connect** connection sometimes sticks 1" short of complete connection both ends. See discussion. **[NOT USED IN NEW SYSTEM]**

C: Connects B to Junction Box. NRH hybrid bulkhead on one side, feed-thru on other. This cable was cut at ODI to allow CT scanning of NRH connection. **NRH connection difficult**, but cable was probably OK.

D, D1: Electrical harness to Seawater Return (SWR). Not used in deep ocean. Testing at SOEST OK, not tested at ODI.

E: Experiment whips. Connect Observatory to frame for connection of experiments. E-cables were re-built and modified at SOEST to improve Internet transmission. These cables were not tested at ODI.

H: Optical dry-mate both ends. Connects Junction Box to Observatory. On dissection at ODI it was found that all eight **pin stems had failed** functionally, likely because of problems in manufacture or assembly. (ultimate failure cause) when the **pressure seal failed** allowing oil to leak into one of the connectors. **[NOT USED IN NEW SYSTEM]**

Discussion.

B1: **Pressure seal failure leaking oil into Proof Module**. This feed-thru was disassembled at ODI to search for the location of the pressure seal failure. All seals are double-radial o-rings and unlikely to fail. No oil was found in the electrical feed-thrus, but oil was found on the stem containing the 4 optical fibers. While not certain, the failure appears to have been a slow leak through the potting around the fibers. Discussions with technicians imply that construction and test procedures instituted since these connectors were obtained would likely have detected this problem. At the time this cable assembly was constructed (2005) methods used did not allow testing of individual connectors prior to final assembly. New qualification procedures at ODI include a helium leak test that would likely have caught this problem.

B1: **Electrical short**. An electrical short had been noticed at sea when Duennebier received an electrical shock while holding the B1 flying connector and the ship's rail. Testing at sea showed a 6 KΩ resistance between the power conductor in the cable and the connector shell, where the resistance should be GΩ. At ODI, the cable was drained and IR resistance was measured between the power conductors at the feed-thru end of the cable and the flying connector shell. After water was added to the hose, this reading showed a short. On disassembly, one of the electrical stems in the NRH connectors was found to have electrical burns consistent with a short circuit between the connector and the case. The insulating boot around this pin is supposed to prevent an electrical short even if water is present in the cable. The burn was not consistent with a poor solder joint.

Figure 2. Optical feed-thru in B1 NRH flying connector. Leakage around or through this assembly resulted in an electrical short (blackened area on right).

B1: **Pressure seal failure in flying connector**: Detailed inspection of the disassembled connector did not show an obvious path for oil to take from the hose to the connector face (or for water from the face to the hose). Inspection of the video taken during disconnect at the cable termination at the observatory and subsequent placement of the flying connector into a holster on the Proof Module shows that the oil observed floating upwards when the connector was placed in the holster had likely leaked oil from the connector face into the housing after or during disconnect and that the torquing of the housing when placed in the holster released the oil. All o-ring seals and sealing surfaces appear to be OK. Inspection of the fiber oil reservoir showed that it was full of oil, as it is supposed to be, and that it did not contain water. One possible path is through one of the electrical pins (Figure 2). This might also explain the electrical short circuit, but no definitive source of this failure was found. The burning of the pin likely occurred on the ship during subsequent testing when power was applied to the cable. Since this cable had operated for 20 months in service, the electrical short could not have occurred on the bottom.

Cable systems A, B, B1, and C: **Connection difficulty**: Difficulty in connecting the flying NRH connectors to their mating bulkhead connectors had been observed at SOEST in early testing, testing at sea, and in connecting A to B on the ocean floor. The symptoms were always the same, the connectors would move together against the spring in the bulkhead connection but stop 1" short of complete connection. No reasonable force would move them together, even if pulled slightly apart and re-tried. The connector had to be removed completely before trying again to obtain connection. Early discussions with ODI had not resulted in any particular concern, and, if enough tries were made, the connections were eventually successful. At ODI, prior to the arrival of Duennebier and Harris, 67 connections between the C and B cables were made without difficulty, but on the 68th try the connection failed, and the connectors stopped 1" short of complete connection. The connectors were left in this configuration so that the new ODI C-T scanner could be used to detect the internal configuration. Unfortunately the scanner was being repaired during the trip to ODI and the scan will not be completed for several weeks.

Disassembly of the B1 flying connector and the other end of B did not show any obvious failure modes. This is a complex connection, and it appears to be well-designed and functional most of the time. We studied a video of this connector showing how internal parts move and took measurements of the motion. As suspected by Harris, the connector is 1" from complete connection when the bulkhead-side fiber stems touch the roller. The obvious conclusion is that when the connection fails the roller is not in the correct rotation. As confirmation of this, Heather Fields, the engineer assigned to work with us, found a working model of the bulkhead connector, and we were able to exactly duplicate this failure mode by manipulating how the actuator interacts with the paddle on the roller. While we cannot be 100% sure that the problem has been identified, we expect that the CT scan of the connector will show that the paddle is in the wrong location. What is not known is WHY the paddle does not always connect with the actuator. ODI says that they have never seen this failure before, but we have observed it on both of the two bulkhead connectors we have (A and C).

This could be a serious problem, in that if too much force is applied when the connectors don't mate, the fiber stems that are pushing against the roller will be broken and the connector destroyed. This could happen to the A connector in the cable termination if the ROV operator pushes too hard. See Figure 4.

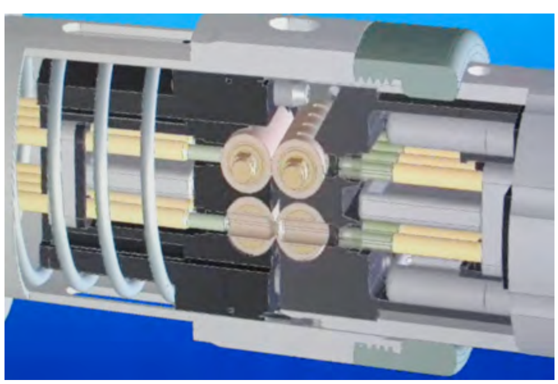

Figure 3. Operation of the ODI NRH rolling seal connector.

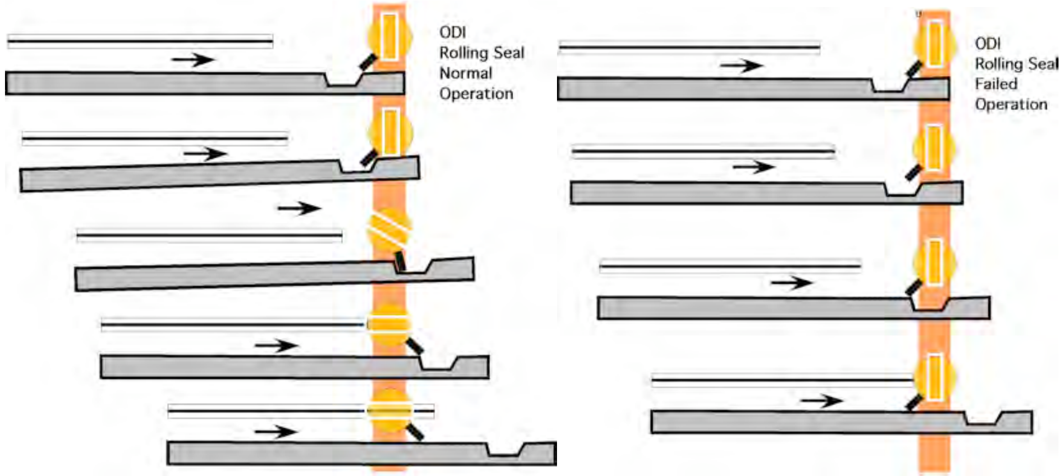

Figure 4. NRH Rolling seal hybrid connector operation. When connection fails, the actuator (grey) fails to engage the paddle (black) that turns the roller.

H: **Failure of fibers to butt, causing high optical attenuation**: This is the failure that caused the ultimate failure of the ACO installation in October, 2008. During initial testing of this optical dry-mate connector, it was noted that fiber #2 had high attenuation, and inspection showed that the fiber stem on one of the bulkhead connectors was pushed in. Since we use only two fibers, the problem was ignored. The system operated nominally, although care had to be taken to tighten these dry-mate connectors securely and take care that an internal o-ring was in place, and there were no indications of any problems until the system was turned on when installed on the ocean floor. The power came on as expected and a clock system from the Junction Box to shore showed that the observatory was being powered and data transmitted from the JBox to shore. However, there was no communication from the observatory through the H-cable. On return to the ship, the H cable was bypassed and the system was again operational. Oil was noticed in one of the H connectors, implying a failure of the pressure seal.

Study of the connectors back at SOEST showed that all four fiber stems on the bulkhead connector where oil had been found on recovery were now pushed in roughly 0.1 inch, and attenuation through the connector was very high on all fibers.

At ODI, the H bulkhead connectors were studied. As designed, a spring on each fiber stem in the bulkhead connectors should allow the fiber tips to butt against each other (Figure 5). An attempt to move the fiber stems in the H bulkhead connectors was not successful, implying that the springs were not moving the stems. On disassembly, a bushing used to seal the stem into the connector was found to be partly extruded on several of the stems and far too tight around all of the stems (Figure 6). While the springs operated when the stems were removed from the assembly, the bushing squeezed the stems too tightly when installed to allow the stem to move against the spring. We surmise that the pressure seal in one end of the cable failed during installation injecting oil into the connector housing and placing a force of more than 50 lbs on each fiber stem, pushing them into the bulkhead connector, where failure of the spring mechanism did not allow them to move back to their normal position. Thus, the combination of failure of the pressure seal and failure of all four of the spring mechanisms caused failure of the installation.

It seems highly unlikely that this part was operating correctly before it was delivered to SOEST. The failure of all eight of the spring mechanisms on the fiber stems (four on each end) likely did not ever operate correctly. Somehow, this failure got past ODI's testing and qualification procedures.

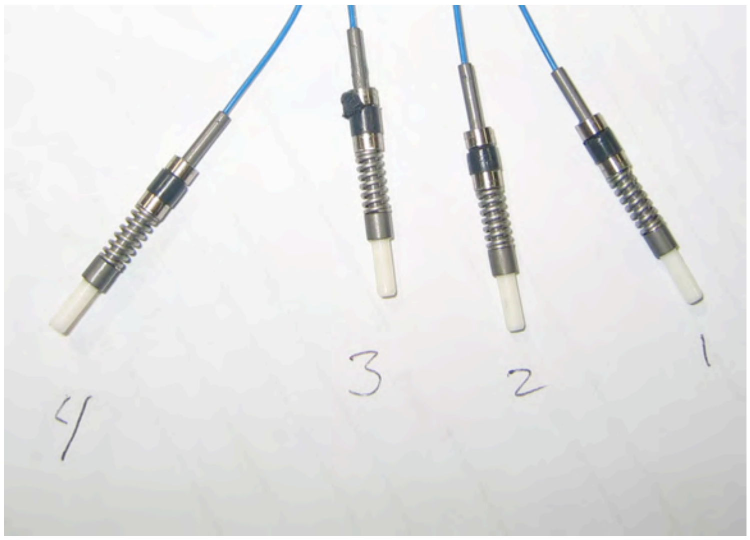

Figure 5. Fiber stems from one end of the H bulkhead connector. The black bushing held the stems too tightly for the springs to operate.

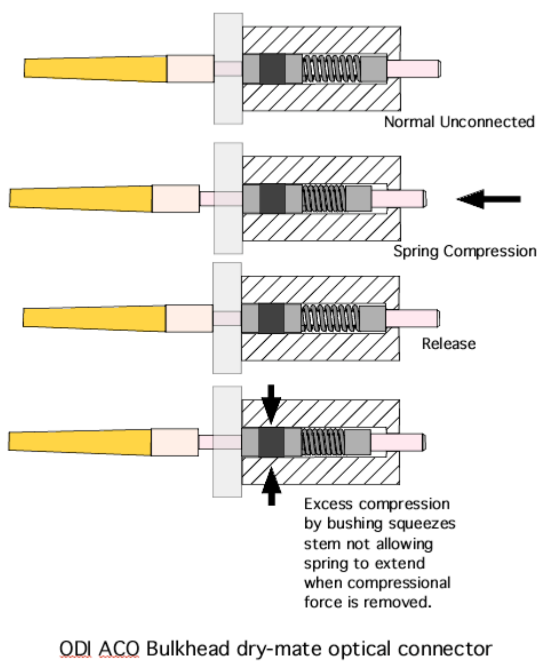

Figure 6. Failure of fiber stem system on Cable H caused by too tight a fit on the black bushing.

Conclusions:

Six failure modes in the ODI connectors and cables purchased for more than $200,000 were discovered:

1. Pressure seal failure, B1 bulkhead connector.
2. Pressure seal failure, B1 flying connector
3. Electrical short, B1 flying connector
4. Pressure seal failure, H dry-mate optical cable.
5. Fiber pin stem failure, H dry-mate bulkhead connectors
6. Connection failure, B-A, B-C, and B1-C hybrid rolling -seal connectors.

Of these failures, none can be ascribed to user errors or unreasonable handling.

Failure 5, observed on all eight fiber connections of cable H, caused the ultimate failure of the October, 2008 ACO cruise.

Subject: STR form - Howe, B/UH_SOEST
From: strs@unols.org
Date: Mon, 27 Apr 2009 17:30:03 -0400
To: bhowe@hawaii.edu
CC: strs@unols.org

UNOLS Ship Time Request Form - Section ONE - Project Information

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Project Title: ALOHA Cabled Observatory
Project Short Title: ALOHA Cabled Observ
UNOLS Project ID #: 101993
Last Modified: 4/27/2009 5:30:00 PM
Project Created By: Bruce M. Howe

Project Status: Submitted
Version #: 4
Date Submitted: 4/17/2009

P.I. Name: Bruce M. Howe
Phone: (808) 956-0466
Email: bhowe@hawaii.edu

Institution: UH_SOEST
Fax: (808) 956-3498

Institution: UH_SOEST - University of Hawaii, School of Ocean and Earth Science and Technology
Address: 1680 East-West Road
Honolulu, HI 96822 USA

Co P.I. Name	Institution	Phone	Email
David Karl	UH_SOEST	(808) 956-8964	dkarl@hawaii.edu
Roger Lukas	UH_SOEST	(805) 956-7896	rlukas@soest.hawaii.edu
Fred Duennebier	UH_Manoa	(808) 956-4779	fred@soest.hawaii.edu

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Science Discipline: Instru
Large Program Abbr: None Selected
If Other Science Discipline, specify:
Large Program Comments:

Project Status: Renewal

Agency/Division/Program	Grant/Project Number	Agency Funding Status
NSF/OCE/OTIC		To Be Submitted

Institutional Proposal #:
Proposal Deadline submitted for:
Project Start Date: 7/1/2009
End Date: 6/30/2011
Project Budget: $863,000

Year	Ship(s) Requested (Name or Size)	Total Days Req.	Start Date	Repeat/Multi-ship/ Clearance Req./Estimated Cost
2010	Kilo Moana	15	7/1/2010	No/No/No/$511,845

Project Webpage: http://kela.soest.hawaii.edu/ALOHA/
Summary of Field Work: Project will install Phase-2.5 of the ALOHA Cabled Observatory (ACO) and experiments.

The junction box pressure case with hydrophone experiment module (HEM) and seawater return will be deployed first and connected to the sea cable termination with JASON. After successful operation is verified, the main observatory node (~2000 lb) will be lowered. JASON will unplug the HEM from the junction box, plug the node into the junction box, and the HEM into the node. The video camera sled will be moved from the node frame to the nearby seafloor. In a subsequent operation, the 200m high thermistor array/acoustic modem (TAAM) mooring system will be deployed, lowered from the ship to a location 50 m from the node. JASON will unspool cable from the base of the

TAAM mooring and connect to the node.

Summary of Facility Requirements: Class-A ship (Kilo-Moana or larger), JASON-2 or equivalent (work at 4720 m). Deck space for JASON vans and deck equipment. Room for science party of at least 22.

Summary of Other Requirements or Comments: Supplemental Funding Request is being submitted to NSF, ~20 April 2009.
Cruise TGT226 in October 2008 attempted installation but was unsuccessful because of failure of commercially supplied optical cabling and connectors.

UNOLS Ship Time Request Form - Ship Request #1 Information

Project Short Title:	ALOHA Cabled Observ	UNOLS Project ID #:	101993
PI Name:	Bruce M. Howe	Version #:	4
Last Modified:	4/27/2009 5:30:00 PM	Date Submitted:	4/17/2009
Institution:	UH_SOEST - University of Hawaii, School of Ocean and Earth Science and Technology		
Funding Agencies:	NSF/OCE/OTIC		

UNOLS Request ID #:	1002922	Last Modified:	4/27/2009
Request Type:	Primary	Date Submitted:	4/17/2009
Submitted By:	Bruce M. Howe		

Year	Ship/Facility	Optimum Start	Earliest Start	Latest Start
2010	Kilo Moana	7/1/2010	4/1/2010	10/1/2010

Dates To Avoid: Need good weather so prefer summer.

	Science Days	Mob Days	DeMob Days	Transit Days (Est)	Total
Op Days Needed	10	2	1	2	15

Multi-Ship OP? No Description:
Repeating Cruise? No # of Cruises: 0 Interval:
Repeating Description:
Schedule Justification:

	Lat/Long	Marsden Grid	Navy Op Area
Beginning:	22.75° N/158° W	88	NP12
Ending:	22.75° N/158° W	88	NP12

Op Area Summary: Station ALOHA
Op Area Size: 2
Op Area Details: Station ALOHA (22 45N, 158 00W) is the site of teh HOT oceanographic program about 100 km north of Oahu.

Foreign Clearance Required: No
Coastal States:
Foreign Clearance Comments:

Start Port: Honolulu, HI, USA
Intermediate Ports: None
End Port: Honolulu, HI, USA
Port Explanation:

Chief Scientist: Bruce M. Howe
in Science Party: 22 # of Science Teams: 1 # of Marine Techs: 2
Science Party Explanation: Require JASON ops and heavy lift (2000 lbs) at 5 km depth

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Instrumentation that affects scheduling
Instrumentation Explanation:

Major Ancillary Facilities

  Jason

Ancillary Facilities Explanation:

ALOHA Cabled Observatory (ACO): Management Plan for Long-term Operations

This renewal proposal includes one year of funding to transition from deployment to sustainable operations. This is necessary to allow time for subsequent proposals for science experiments and sustained operations to be written, reviewed, and funded. The management plan for this nominal 1-year transition period is given in the main body of the proposal. Here we lay out our current view of a long-term management plan and the resources necessary for sustained operations.

We make use of our earlier experience with the H2O observatory, the operation of the ACO proof module, on-going experience with the Hawaii Ocean Time-series (HOT) program, and our interaction and involvement over the years with VENUS, NEPTUNE and the OOI planning process. We follow the NSF guidance for MRI instrument maintenance and operation plans. We have borrowed heavily from the MARS web site and have benefited from discussions with MBARI investigators and their experience with MARS (S. Etchemendy, personal communication).

Overview

The mission of the ACO is to provide sustained power and communications infrastructure supporting science experiments and deep-sea technology development at the time-series Station ALOHA. The ACO is the only abyssal observatory planned at this time, and it will enable new sensors and technology to be rigorously tested over long duration at great depth. It is expected that over time additional infrastructure, such as the ALOHA-MARS mooring system, will extend the power and communications capabilities from the seafloor through the water column. ACO will not only enable ocean scientists and engineers to directly monitor their instrumentation on the sea floor and through the ocean above, but also to modify their software based on real world sensor inputs and changing scientific priorities.

The guiding principles of the ACO are:

- Open access to all investigators,
- All data is publicly available, and
- The ACO operations team will provide a user-friendly and supportive environment for interacting with the system.

The ACO will be operated by UH/SOEST through NSF grants. This initial grant supporting deployment and the transition to operations will be for 2 years with subsequent proposed grant periods of 5 years. Assuming successful deployment in summer 2010 and a successful operations proposal, the initial operations grant would likely start in summer 2011.

User Support

Proposal Planning and Pre-deployment. ACO Operations and Maintenance (O&M) will provide prospective users with support to estimate ship and ROV time to deploy and recover their experiments as well as the shore-side engineer and technician time required to test equipment prior to deployment. In this regard, we will work with MBARI and the OOI as appropriate to optimize the testing process, e.g., using other facilities and assisting potential users by providing a list of engineering resources that could fit their needs.

Deployment. Experiment siting and deployment relative to other experiments is an important issue that requires early engagement of ACO expertise. We want to provide routine maintenance cruise opportunities that hopefully would be augmented by individual grants. During those cruises, ACO personnel would be on board and orchestrating the work. Their time would be supported by the O&M grant for ACO.

Operational Support. Instruments deployed on ACO are the sole responsibility of the user. If an ACO user needs power adjustments, instrument recovery, or other support over the course of a deployment, it will be addressed during normal working hours. To be cost effective, ACO will operate on a normal work-week schedule to minimize personnel costs. ACO will have DMAS (Data Management and Archiving System) capability only for its own engineering data and the data from the core sensors (this proposal). ACO will direct data connectivity to a user-supplied IP address (as MARS does). If necessary, the ACO will assist in pairing an investigator with a DMAS group; it is expected that in the not-too-distant future, the OOI cyberinfrastructure effort will accommodate ACO data. The open data policy shall in all cases prevail.

Users, ports, and costs

We believe that the ACO O&M costs should be distributed fairly to the actual users and NSF should not bear the full burden of the ongoing operations and maintenance costs. To achieve this objective we propose a minimal fee of $1000/month (as per MARS) for each project either funded by NSF or to those whose objective is to develop ocean observatory technology using one of the ACO ports. The intent of this fee is help pay for maintenance and other costs after the first year. We will also require a fee equaling a fair share of the operational costs from other U.S. government funding agencies to use ACO, as these agencies may have objectives not directly linked to NSF. The ACO science port fee rate will be governed by annual discussions with NSF with dual objectives of providing a repair reserve and regulating ACO user science port use.

The following priorities will be followed for ACO projects (borrowing heavily from MARS):

1. Owners (i.e., NSF and UH): NSF-funded science projects and projects developing technologies for ocean observatories (e.g., OOI and OOI2) are given first priority. NSF and UH have funded the development of the ACO and the many supporting technologies that made the facility a reality. Therefore, a minimal port cost rate for first tier “Owner” projects recognizes NSF’s and UH’s ongoing support of the ACO.
2. Fair Share (all other Federal agencies and non-profit organizations). The second tier is U.S. agencies that make contributions to ocean science and development but did not support the development of ACO or ongoing O&M costs. This tier is labeled “Fair share” because the port costs will be calculated based on operating costs for the ACO O&M divided by the ports and prorated on a monthly basis.
3. Commercial/Foreign (vendors and foreign oceanographic institutions). The “Commercial/ Foreign” rate is normally twice the fair share rate. The ACO may choose to make exceptions to this rule based on technology development directly applicable to NSF goals.
4. Other. This category includes users sponsored by university, NGO, and other sources as well as users daisy chained to already-connected experiments; rates will be determined at the discretion of the ACO (as per MARS).

ACO users must budget for ship and ROV costs, cable, connectors and interface electronics if necessary. The ACO makes use of the MARS and OOI standard Science Port Interface that will simplify interfacing new and existing equipment to the ACO. ACO users are encouraged to use the ACO manager as a resource in planning their proposal. An ACO proposal may need to include a request for technical support from UH.

Governance

ACO O&M is governed by policies agreed upon between the project and NSF, with input from the Advisory Committee and OOI. The ACO Science and Technology Advisory Committee is made up of representatives of the oceanographic science and technology community and the ACO O&M PIs (ex officio); the current committee consists of Bruce Cornuelle (UCSD), Steve Etchemendy (MBARI), Dan Frye (WHOI), Scott Glenn (Rutgers), Bruce Howe (now at UH; will be replaced), Marla Meehl (UCAR), and Bob Weller (WHOI). The committee will assist the project with schedule and performance reviews, and with advice on policy and resolving use conflicts and on attracting new users. The Committee will meet in person on a biennial basis and more frequently by voice and email.

Facility

The current ACO shore equipment at UH is located in Howe's lab space (shared with other ocean observing projects). With a funded operations grant, UH/SOEST will make available dedicated lab space (approximately 200 sq ft) for the control computers, equipment maintenance, and lab testing of new science experiments. The leasing of the AT&T Makaha shore station space and the T1 line will continue (the latter may need to be upgraded if more high-bandwidth sensors are added).

Staff

The Operations Manager is responsible for maximizing the technical success of ACO users. Additionally, the ACO Operations Manager is the primary resource to assess deployment "readiness" of science experiments as well as any infrastructure component of ACO. This individual is responsible for technical transfer of information between ACO and other NSF activities (e.g., OOI) and provides maintenance oversight, including managing maintenance support by the original ACO design team.

The Facility Support Technician is responsible for the day-to-day control of the ACO system.

A junior engineer will fill these two roles during the transition year, with training from the development engineers. Subsequently, this individual will become the manager with support from a technician.

Part-time personnel will be utilized as necessary to fill in expertise, e.g., web page updates, core sensor quality control and maintenance, specific design work, new software, outreach, etc.

Two co-PIs are expected, one to concentrate on operations and technical aspects and one on science aspects. The first would addresses insurance, manning, and reporting obligations with NSF. He represents ACO O&M for UNOLS ship scheduling functions. The second co-PI provides scientific oversight, addresses policy issues and resolves science conflicts (e.g., one instrument affecting another) working with the Science and Technology Advisory Committee. Both will be involved in the core sensor data quality assessment and the associated analysis.

It will be the responsibility of the co-PIs and operations manager to publicize the ACO and results in the ocean science and technology communities to attract new users. This will take the form of conference presentations and posters, participation in workshops, community publications such as *Eos* and *Oceanography* and journal publications.

Annual Operating Costs

The annual operations cost is estimated in the following table. The operations manager, technician and other technical support are lumped together here as 1 FTE engineer ($17K/month); UH will contribute 30% of the latter. Other includes travel (including biennial STAC meeting), UH networking services, lab and field supplies, etc.

Table 1. ACO fully burdened estimated annual costs

	Cost $K/year
Technical support, total 0.7 FTE engineer	140
Co-PIs, total 2 months per year	60
Makaha shore station lease	45
Insurance	45
T1 line	15
Other	75
Total	380

We anticipate requiring UNOLS ship and ROV time to maintain the infrastructure and core instrumentation. Determining the amount of time and frequency will be an iterative process. For now we suggest a minimum of 5 days every other year, providing a base upon which users could increment to support their ACO related activities.

Bio•Waves

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April 24, 2009

Dear Sir or Madam:

This is a letter to express our support for the re-installation of a hydrophone at the Station Aloha Cabled Observatory (ACO) and the addition of a second hydrophone. We are currently working with acoustic data collected at the ACO during 2007/2008 to examine trends in the occurrence of minke whales in Hawaiian waters. This work has been part of Julie Oswald's post-doc at the University of Hawaii and was presented at the 156th meeting of the Acoustical Society of America, Miami, Florida, Nov 10-14, 2008. In addition, these data will used as part of a project that has recently been funded by ONR to assess the distribution, abundance, acoustic behaviors, and effects of noise on minke whales (ONR proposal entitled: 'Beaked Whale and Minke Whale Presence, Habitat, and Sound Production in the North Pacific).

While the existing ACO hydrophone data are valuable, it would be an enormous asset to be able to collect more data to augment them and to coincide with other field data being collected under the ONR project. In addition, the ACO hydrophone allows us to examine the presence and vocal behavior of many other marine mammal species over long time-scales that would not be possible using other methods such as ship-board surveys.

The installation of a second hydrophone at the ACO is, in our opinion, not only worthwhile, but necessary. With only one hydrophone it is difficult or impossible to localize sounds detected at the ACO, severely limiting the amount of information we can glean from the recordings. The addition of a second hydrophone provides localization capabilities, making it possible to answer questions about source levels, number of sound sources present, movement of sound sources, etc. This additional information would greatly improve our understanding of the behavior and ecology of marine mammals in these waters.

Please do not hesitate to contact us at oswald.jn@gmail.com if you would like to discuss these matters in more details.

Sincerely,

Julie Oswald

Julie Oswald, PhD

Tom Norris

21 April 2009

Dr. Bruce Howe
School of Ocean and Earth Science and Technology
University of Hawaii
Honolulu, HI 96822

Dear Bruce,

We are very excited about the completion of the first phase of the long term cable installation at Sta. ALOHA. It was a disappointment to hear about the failure of the optical connectors during phase two but it is now apparent you will proceed with this very important project. The proposed installation of acoustic Doppler current profilers, thermistor array, hydrophones, bio-optical sensors and video camera will greatly enhance the ability to characterize the abyssal environment at this critical long time-series site. Your proposed installation would significantly complement the benthic installation we would like to propose.

We would like to monitor Sta. ALOHA with the same instrumentation that was developed for inclusion at the Hawaii-2 Observatory (H2O) site. Our instrument platform consists of a time-lapse camera and sensor package for quantifying settling particles and phyto-pigments (NSF, OCE- 0002385). A strong coupling exists between benthic community processes and pelagic production at Sta. ALOHA (Smith et al., 2002) where long-term changes in plankton community structure and productivity are documented. Your proposed water abyssal environmental monitoring with real-time data acquisition would greatly enhance our ability to interpret biogeochemical processes in the benthic boundary layer measured with our proposed benthic sensor systems.

I enthusiastically support your proposed completion of the installation of the ALOHA Cabled Observatory so that it will be operational and available for other instrumentation plug-ins such as our benthic sensor system.

Sincerely yours,

Kenneth L. Smith, Jr.
Senior Scientist

UNIVERSITY OF HAWAI'I AT MĀNOA
School of Ocean and Earth Science and Technology
Department of Oceanography

April 23, 2009

Dr. Bruce Howe,

We enthusiastically support your proposal to complete the cabled observatory at Sta. ALOHA. We have been anxious for its completion because it will provide a unique opportunity to study abyssal ecosystems, the largest in the biosphere. Most components of the Global Ocean Observing System (MOR, NEPTUNE, MARS, European margin) monitor "marginal" deep-sea habitats. The instruments on the ALOHA observatory (video camera, bio-optical sensors, Doppler current profilers, and more) will provide a unique dataset with which to relate changes in the **abyssal** ecosystem to forcing from the surface ocean based on data from the HOT Program and other Hawaiian process studies. Upon completion of the observatory, we plan to propose emplacement of high resolution cameras and sensors to monitor the flux of detritus to the seafloor, feeding activities of megafaunal deposit feeders and scavengers, and rates and patterns of bioturbation. These processes can provide key insights into abyssal ecosystem function and may serve as indices for export flux from the euphotic zone, as shown by previous time-series studies at Sta. ALOHA and regional studies in the abyssal Pacific (e.g., C. Smith et al., 2008, Drazen et al., 2008). Long time-series observations of the abyssal plain in the North Pacific central gyre will provide an exciting window on climate induced changes in the largest benthic ecosystem on the planet. The observatory's power and real-time data transfer capabilities create the opportunity to compose such a time-series, with responsive sampling during periodic export events and peaks of benthic faunal activity.

We fully support your proposal and are eager to collaborate, including in the analysis of images acquired from the proposed real-time video camera. We also look forward to the completion of the ALOHA observatory so that we may "plug-in" our own specially designed experiments.

Sincerely,

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