ALOHA Cabled Observatory Installation

Bruce M. Howe, Roger Lukas, Fred Duennebier, David Karl
School of Ocean and Earth Science and Technology
University of Hawaii at Manoa
Honolulu, Hawaii, 96822 USA

***Abstract*— At 10:23 am on 6 June 2011, the ALOHA Cabled Observatory (ACO) saw "first light," extending power, network communications and timing to a seafloor node and instruments at 4726 m water depth 100 km north of Oahu. Station ALOHA is the field site of the Hawaii Ocean Time-series (HOT) program that has investigated temporal dynamics in biology, physics, and chemistry since 1988. HOT conducts near monthly ship-based sampling and makes continuous observations from moored instruments to document and study climate and ecosystem variability over semi-diurnal to decadal time scales. The cabled observatory system will provide the infrastructure for continuous, interactive ocean sampling enabling new measurements as well as a new mode of ocean observing that integrates ship and cabled observations. The ACO is a prototypical example of a deep observatory system that uses a retired first-generation fiber-optic telecommunications cable. The system was installed using ROV *Jason* operated from the R/V *Kilo Moana*. Here we provide an overview of the system and instrumentation, the installation operation, and a sample of initial data. Sensors now connected to the ACO provide live video of the surrounding seafloor, sound from local and distant sources, and measure currents, pressure, temperature, and salinity.**

Keywords-ocean observing; sustained sampling; ocean acoustics; seafloor video; abyssal flow

I. Introduction

Over the last several decades progress has been made on developing and operating seafloor cabled ocean observatories, using purpose built systems and existing retired telecommunications systems. Examples of the former are the NEPTUNE Canada system in the northeast Pacific [1] and the DONET system off the coast of Japan [2]. An example of the latter is the H2O system halfway between Hawaii and California that operated between 2000 and 2003 [3].

The ALOHA Cabled Observatory (ACO) is a deep ocean observatory 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 are substantially lower than for new systems. In the simplest terms, we want to provide power and communications ports for users to plug into on the seafloor for instrumentation to serve science. Here we include sensors for measurements of water properties, video and acoustics.

ACO is funded by the National Science Foundation and the School of Ocean and Earth Science and Technology at the University of Hawaii at Manoa.

The motivation for the ACO arose from the Hawaii Ocean Time-series (HOT) program operating at Station ALOHA 100 km north of Oahu, Figure 1. This program has and continues to investigate temporal dynamics in biology, physics, and chemistry [4-9]. HOT conducts near monthly ship-based sampling and makes continuous observations from moored instruments to document and study climate and ecosystem variability over semi-diurnal to decadal time scales. The cabled observatory system will provide the infrastructure for continuous, interactive ocean sampling enabling entirely new measurements as well as a new mode of ocean observing that integrates ship and cabled observations.

In February 2007, the AT&T HAW-4 cable was cut and relocated 20 km to Station ALOHA, Figure 1. For twenty months a hydrophone and pressure sensor "proof module" sent data to shore [10]. References [11] and [12] present analyses of the acoustic data from the perspective of surface wave-wave interaction and marine mammals, respectively. A subsequent attempt in October 2008 to deploy the complete system with a general-purpose node and additional instrumentation failed due to faulty connector and cable assemblies. Since then the system has been improved and just recently installed.

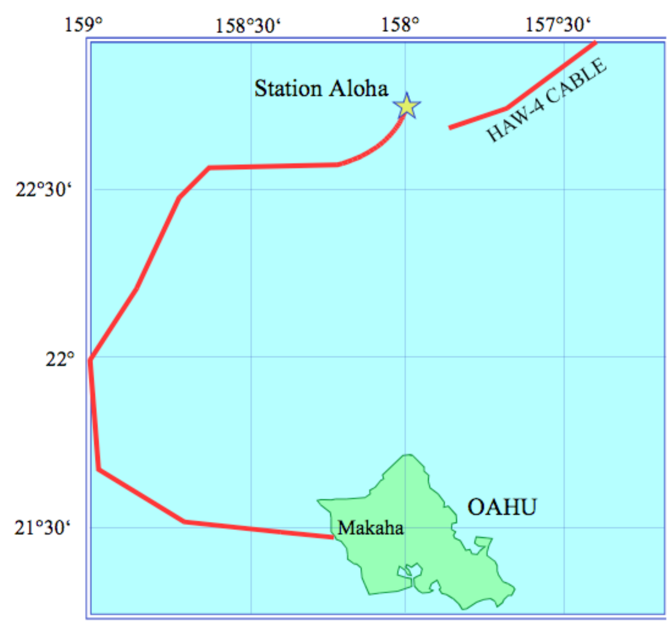

Figure 1. Map showing the Makaha cable station, the cable and Station ALOHA.

In the following sections we provide an overview of the installed system, including the primary and secondary infrastructure and the instrumentation (Sections II and III). The installation is described in Section IV. Sample data are presented in Section V followed with concluding remarks in Section VI.

II. Primary Infrastructure

The technology used in ACO is based on the HUGO and H2O observatories, with improvements based on lessons learned from both [10,13,14], as well as from the October 2008 attempted deployment [15]. The current system elements as deployed on the seafloor are shown in Figure 2 in mosaic form and in schematic form in Figure 3 and 4.

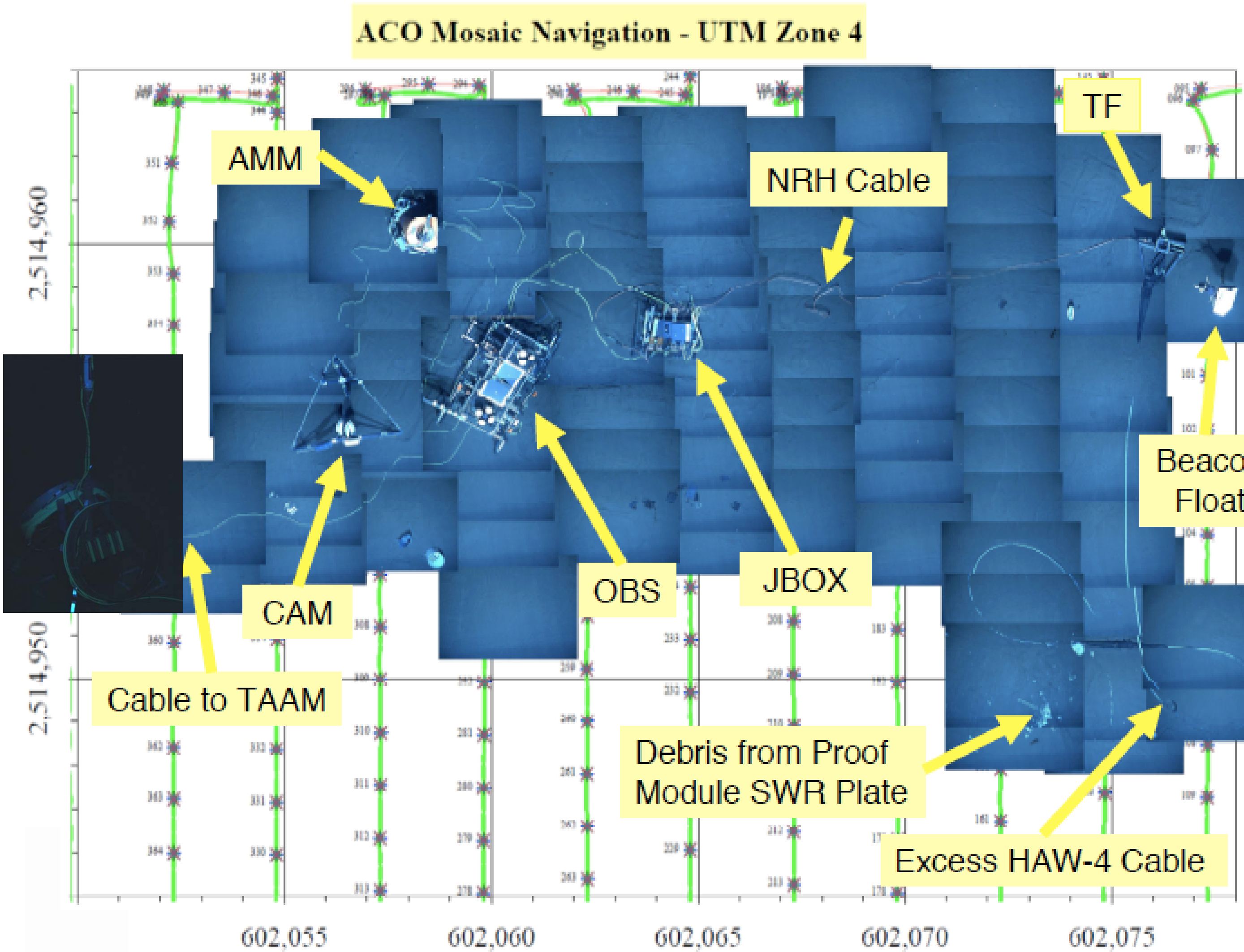

Figure 2. Mosaic of components on the bottom. The TAMM is 50 m WNW.

A. Shore station, cable, and termination

At the AT&T Makaha shore station, the shore power system supplies the single conductor sea cable with a constant current of 1.6 A at a voltage that varies depending on load, up to 1270 V for the present observatory configuration. At the seaward end of the three fiber-pair cable is a titanium and fiberglass frame with the cable termination, an Ocean Design, Inc. (ODI) hybrid electro-optical two fiber pair wet mate connector. In a splice just before termination, one fiber pair is looped back.

A special "muldex" circuit board provides the interface between the AT&T Time Division Multiplexing (TDM) 280 Mb/s cable system (state of the art in the 1980s) and 100 Mb/s Ethernet [14]. A dedicated 3 Mb/s link connects the ACO equipment at the shore station to the University of Hawaii (UH). A Tekron TCG-01-E grandmaster clock synchronized to GPS time provides system time at the sub-microsecond level using the IEEE-1588-v2 precision time protocol (PTP). Hirschmann MS-20 Ethernet switches in the shore station and subsea in the junction box operate in "transparent clock" mode to transfer precise time.

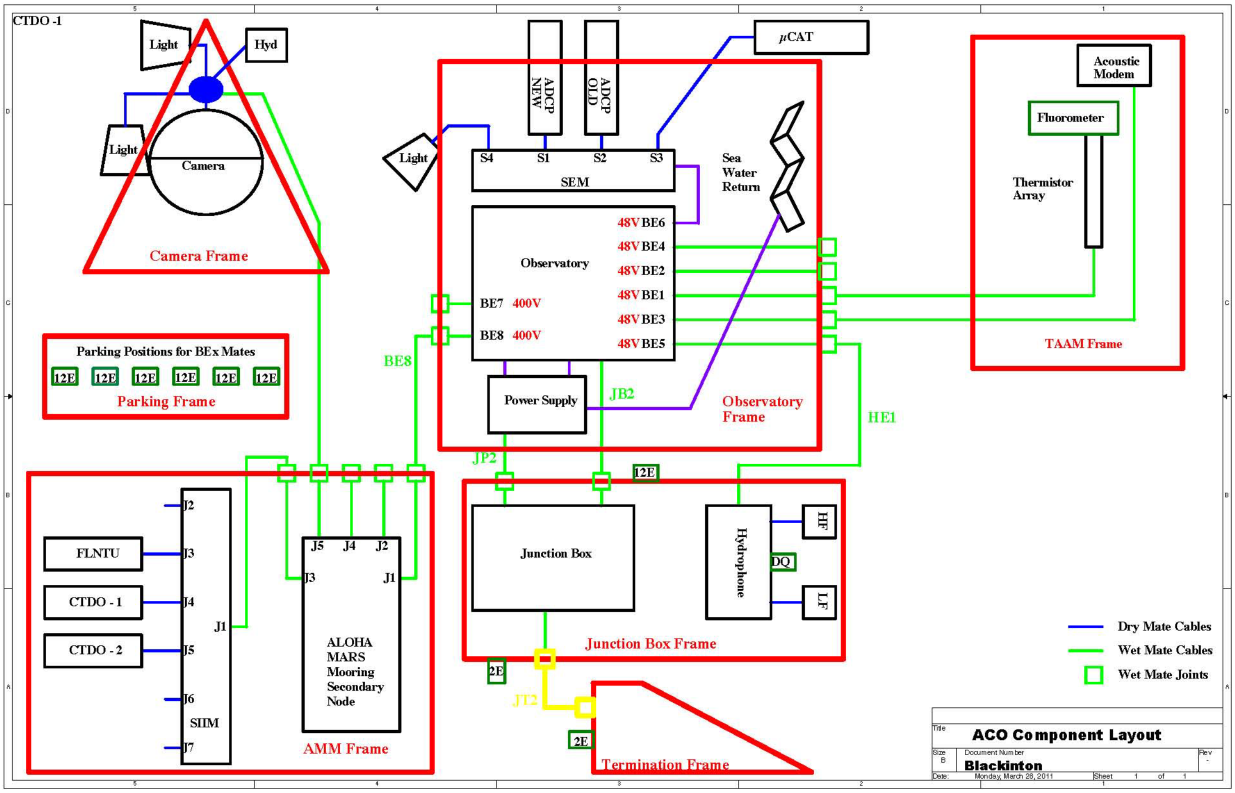

Figure 3. Overall system schematic with connections between the various components.

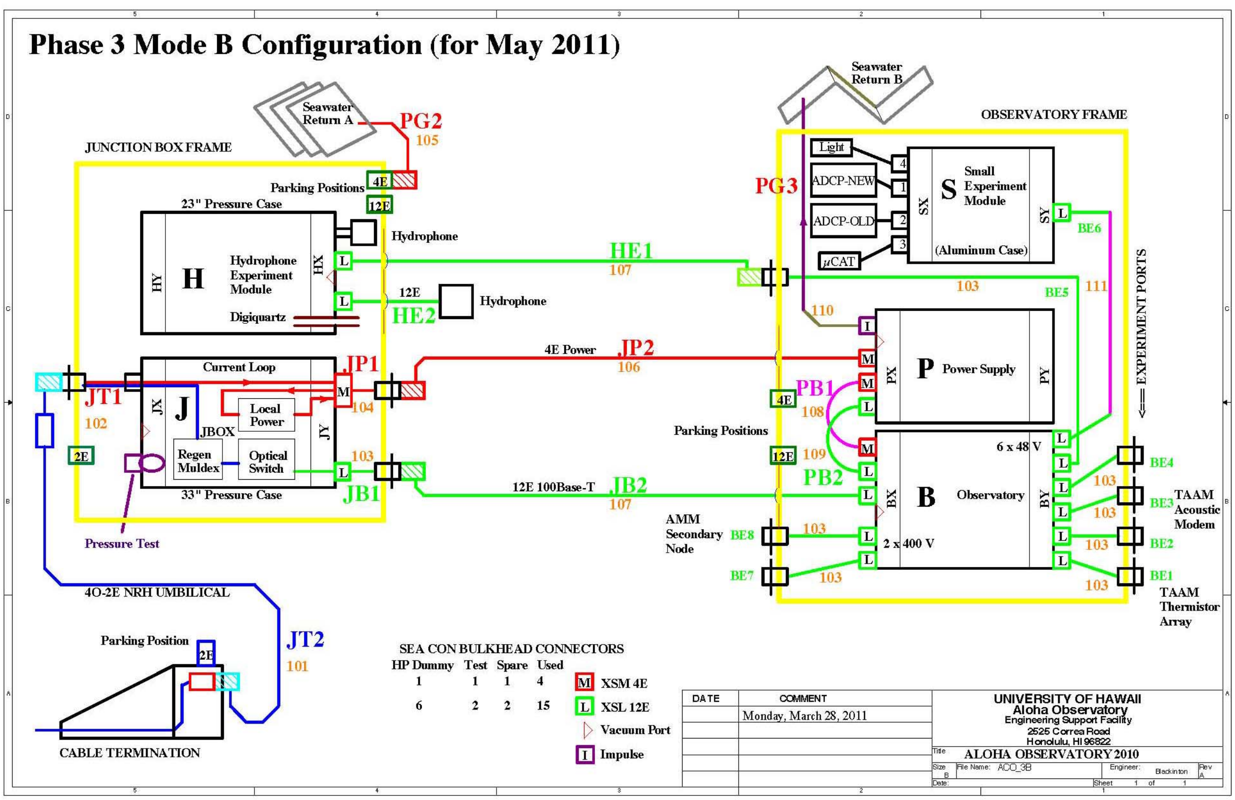

Figure 4. JBOX and OBS schematic.

B. *Junction Box*

The primary purpose of the junction box is to interface the cable communications protocol on the sea cable to electrical Ethernet to serve the balance of the observatory. A SL560 repeater/regenerator unit has been modified to do this with the addition of a muldex board and Hirschmann Ethernet switch, just as in the shore station. A Tekron TTM-01-E PTP client unit is used to generate a 1 PPS signal. An additional circuit board with a Digi RCM3000 "rabbit" microprocessor generates an IRIG-B timing signal from the 1 PPS while buffering the latter. There are three zener diode power supplies each delivering approximately 24 W, one for the regen and muldex, one for the other circuitry, and one for external use at 48 V.

The 48 V, 100 Mb/s Ethernet, 1-PPS, and IRIG-B are provided on a 12-pin ROV wet mate connector. Normally this is connected to the observatory module, but it can also be connected, for example, to the hydrophone experiment module (HEM) so the combination becomes a "proof module." The JBOX frame with junction box and HEM are shown on the R/V *Kilo Moana* fantail before deployment in Figure 5.

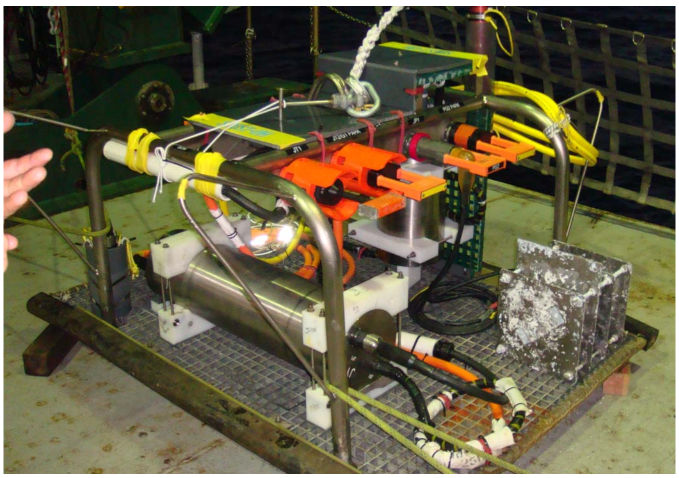

Figure 5. JBOX frame with the junction (horizontal), HEM (vertical), and seawater return (right).

C. *Observatory*

The observatory frame holds the main power supply and the observatory module as well as instruments, Figure 6.

1) *Power supply*

The observatory application requires more power and flexibility than can be provided by a zener diode circuit. Active current shunts that consume the excess power if the load power decreases are used. The power consumed by the shunts is controlled by sensing the input voltage to the converter. If the voltage is higher than desired, the current is increased to return the voltage to the correct level. The power consumed by the shunts is converted to heat in resistors and dissipated in the surrounding water. The ACO power supply uses 8 convertors, each with a 100 VDC nominal input and a regulated 48 VDC output. Each convertor can provide 160 W. The 48 V is supplied to the observatory module on two buses, one for hotel load one for user ports. A rabbit microprocessor controls startup and operation/monitoring and communicates with the observatory module via Ethernet. Further detail can be found in [13] and [15].

2) *Observatory module*

The observatory module provides eight user ports each with Ethernet, 1 PPS and IRIG-B. Two of the ports provide 400 V (up to 300 W), five ports provide 48 V (up to 150 W), and the last port provides 48 V directly from the user bus for high current loads. All ports but the last are isolated via DC-DC converters. Via software control, four of the 48 V ports can be routed to a serial port server to support instruments with serial communication. Multiple rabbit processors are used for control and monitoring voltages, currents and temperatures. Three Sixnet Ethernet switches provide multiple redundant connections. The user ports are "observatory standard" 12-pin ODI bulkhead connectors. Instruments from other observatories such as NEPTUNE Canada and MARS can be directly connected to ACO.

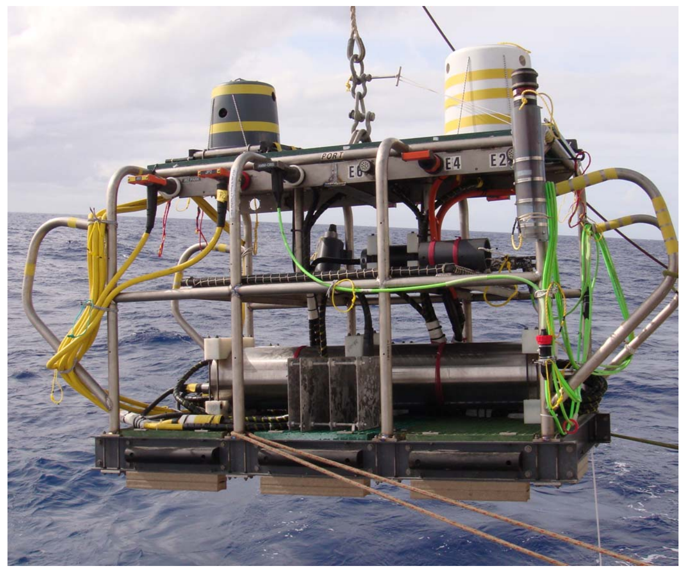

Figure 6. Observatory frame (OBS) being deployed. Power supply and observatory module with seawter return are on lower deck, µSEM on mid-deck, and CT, ADPs (with protective covers), and light on upper deck.

D. *Network and command and control*

A secure and configurable network is essential for reliable observatory operation. All Ethernet switches are managed. Sonicwall firewalls are used at the cable station and at UH to control access and to configure virtual local area networks with managed access. Access is possible from anywhere in the world, from computers and mobile devices. Adrem software is used for network monitoring.

On the primary shore command and control computer at Makaha, two programs control and monitor the basic operation of the system. ACO_engine provides the single interface to the subsea system and logs all interactions with little user interaction once started. The ACO_client is the main user interface with a graphical user interface. Here one can monitor and change settings on user ports and the power supply. All the engineering data reported by the nine subsea rabbit microprocessors are logged.

III. Secondary Infrastructure and Instrumentation

Secondary infrastructure components are between the user ports and instrumentation. At the simplest level, this would include cable and connector assemblies that directly connect instruments to the primary observatory module.

A. Micro-Science Experiment Module (μSEM)

The simple μSEM has a power supply and a Digi TS4 serial port server. It is the interface between a user port and the instruments on the observatory frame: Seabird Electronics SBE-37 conductivity and temperature (CT), two Sontek 250 kHz acoustic Doppler profilers (ADPs), and a DSP&L Multi-Sealite LED light. The latter is turned on with the initiation of a telnet session that flips a control bit in the TS4.

The CT sensor and the light are mounted on flip arms on the top of the observatory frame at opposite ends. After deployment the flip arms increase the distance of the sensor/light from the frame. For the temperature sensor, this is to minimize possible heating influences from the power supply and observatory modules below. For the light it increases the illumination coverage of the observatory for the camera. The ADPs are mounted on top of the observatory frame pointed up such that the beams do not overlap.

B. Hydrophone Experiment Module (HEM)

The HEM is configured to run off either the junction box or from a normal observatory port. There are two hydrophones. One is an OAS Model E-2PD meant for low frequencies (0.01 Hz to 10 kHz; see [11]). A second (uncalibrated) hydrophone is meant for higher frequencies. Data acquisition is controlled with a PC-104. Gain and filter settings and data rates can be changed via the user interface. The offset between the 1 PPS and the local clock is recorded in the header of every 4096 sample data block, so that absolute time can be recovered. Current sampling rates for both hydrophones are 96 k samples/s.

Because of the currently low bandwidth available between the Makaha cable station and UH, raw data files are archived locally on a RAID system. Low-pass filtered and decimated data are sent to UH for audio streaming purposes. In addition, power spectra are computed from the raw data and these are also sent to UH. With the audio and spectrograms, periods of interest can be identified and raw data retrieved.

The HEM also hosts a high precision Paroscientific Digiquartz pressure sensor. The frequency counting is set up so that arbitrarily long averaging periods can be chosen when analyzing the data.

C. Video camera system

The Axis-214-PTZ Internet surveillance camera with pan, tilt and zoom is mounted in a Nautilus 432 mm diameter glass sphere. The sphere is suspended in a ring structure near the upper vertex of a tetrahedron frame 2.5 m on a side made from PVC, Figure 7. Two lights are mounted on the frame, one configured to point down just outside the frame and the second out farther in the same direction. An ITC 1072B hydrophone is connected to the audio input on the camera via a preamplifier and filter.

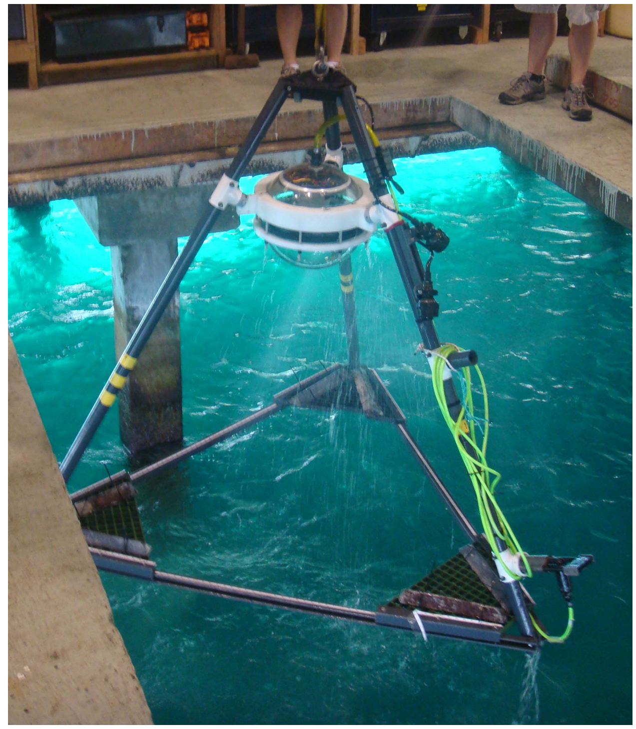

Figure 7. Camera moiunted in tripod during testing at Makai Pier.

D. Thermistor Array and Acoustic Modem (TAAM) mooring

The 230 m high TAAM mooring consists of two parts, the thermistor array and the WHOI acoustic micro-modem (Figures 8 and 9). The array consists of 10 Seabird SBE39-IM thermistors and a Wet Labs FLNTU fluorometer. Two of the SBE39s at the top of the mooring measure pressure. These instruments are mounted on jacketed wire rope (JWR) and communicate with a SBE inductive modem unit that is in turn connected to the observatory via a seafloor cable. The acoustic modem (operating in the nominal 10 kHz band) is connected to the observatory via an electrical riser cable married to the JWR, and a seafloor cable.

E. ALOHA-MARS Mooring (AMM) Secondary Node

To increase the number of user ports available on the bottom, we deployed the AMM secondary node, Figure 10. This uses one 400 V ACO observatory port and provides one 400 V and three 48 V output ports. It was developed at the Applied Physics Laboratory, University of Washington (APL-UW) as part of the NSF funded AMM project [16].

F. Science Instrument Interface Module(SIIM) and Sensors

This SIIM, provided by APL-UW with the AMM node, is similar to the μSEM, though with an Ethernet switch and Digi-Connect modules for each of its 8 ports. It was hard mounted to the AMM secondary node along with two pumped SBE-52/43 $CTDO_2$ instruments and a Wet Labs FLNTU fluorometer (Figure 10).

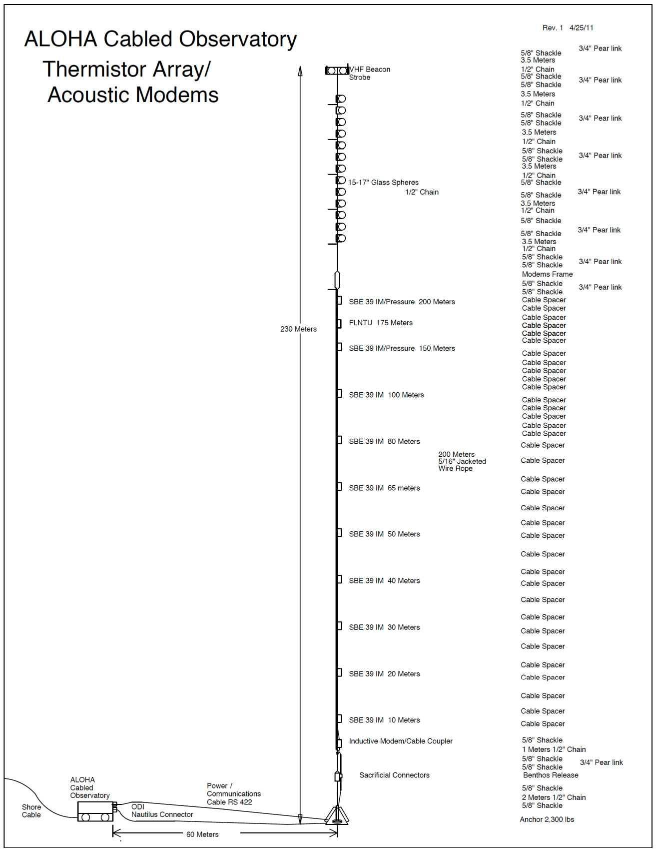

Figure 8. TAAM mooring diagram

Figure 9. TAAM mooring anchor and cables. The acosutic release is at the top.

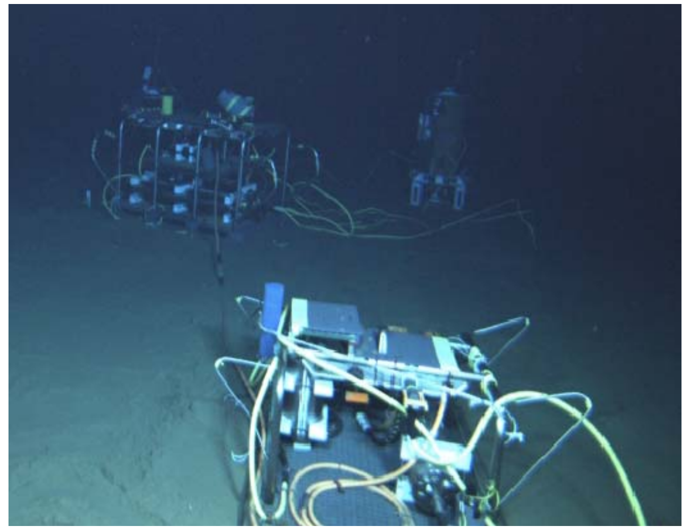

Figure 10. JBOX (foreground), AMM secondary node (upper right), OBS, and Camera (back left)

IV. Installation

The R/V *Kilo Moana* with ROV *Jason* (Figure 11) were used to deploy the ACO system between 20 May and 7 June 2011. *Jason* is a two-body ROV system. A fiber-optic tether delivers electrical power and commands from the ship through *Medea* (the second body) and down to *Jason*, which then returns data and live video imagery. *Medea* serves as a shock absorber, buffering *Jason* from the movements of the ship, while providing lighting and a bird's eye view of the ROV during seafloor operations. On this cruise, the ship's 0.681-inch electro-optical-mechanical cable was used as the umbilical to *Medea*. Ultra-short baseline and Doppler velocity log were the primary inputs to the navigation system.

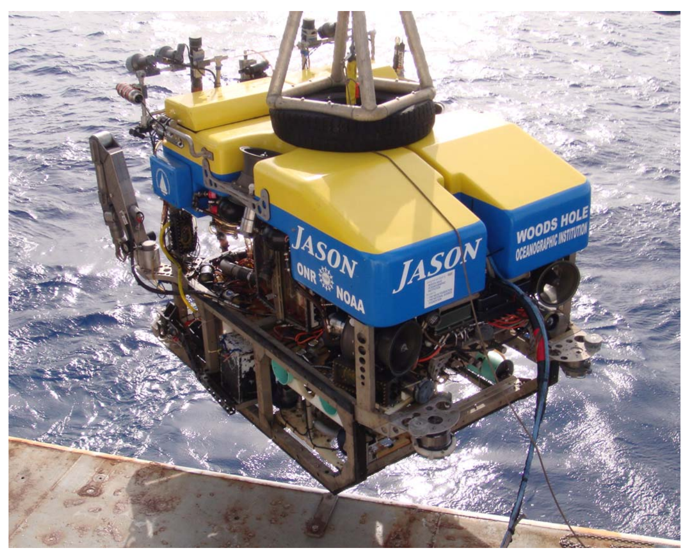

Figure 11. ROV *Jason*

When deploying the ACO components (JBOX or OBS), three packages were in the water at one time. The ACO component was deployed first and secured at 20 m depth with a Y-bridle. Then *Jason* was deployed and streamed out behind the ship on its tether connected to *Medea* still on deck. The ACO load was transferred to *Medea* and the latter deployed. As bottom was approached, a plumb line with a small weight intermittently touched bottom (~ship heave) raising a small silt cloud. Jason could see this, and *Medea* (and the ship) and the ACO component were moved to the desired location.

Upon arrival at the ACO site, a survey dive (Dive 1) was conducted to locate the cable termination and replace the homer beacon. The termination frame was moved several meters north to clear a small wuzzle of sea cable. After the JBOX was connected the first time, it was clear a major fiber connection problem existed. The next five ACO dives were related to debugging the fiber connections with changes being made to the fiber configuration in the JBOX. Because we finally felt the problem lay in the sea cable and could only be fixed on shore (with possibly a change in the JBOX), we decided to install all the subsea components while the shore personnel continued to work on sea cable configuration. During this time, the AMM secondary node and the camera were dropped by freefall and positioned near the observatory.

On 3 June, the TAAM mooring was deployed. The mooring landed in the desired location about 50 m WNW of the JBOX location. Later the same day, the observatory (OBS) was deployed successfully, but the dive had to be aborted when the lowering bridle was caught in *Jason* thrusters. After a 45-minute turn-around, *Jason* redeployed (Dive 8) to move and connect the AMM secondary node, move and connect the camera (CAM), and connect the TAAM. The acoustic modem seafloor cable was connected first. We returned to the mooring to deploy the IMM seafloor cable, but found the IMM-seafloor connector had parted and so that cable was not deployed. During this time an ODI hybrid test connector mounted on *Jason* and using its telemetry system was mated to the sea cable to provide further diagnostic data.

The results from the latter indicated a clear light path, but the JBOX had to be recovered (Dive 9), reconfigured and redeployed (Dive 10) and connected. At 0905 6 June HST, the ship received notification that Ethernet was functional; hydrophone signals sounding like *Jason* could be heard at UH. Then the subsea connections were reconfigured to connect the JBOX to the OBS. At 1023 6 June HST, sensor data started flowing. Jason left bottom at 1500 to return to port on time.

A multitude of factors caused the problems with the sea cable/fiber configuration. There was a basic error in fiber assignments between the sea cable and the ODI connector. A new software program (PALMS) was being used to check the status of the sea cable (repeater settings, received light power at each repeater, laser output bias current, light path routings, etc.). This program had been tested and used on other systems. However, our system had problems, partly associated with the RS-232 computer interfaces and variability therein. Part way through the evolution, it was discovered that two fibers were reversed on the back of the Terminal Transmission Equipment (TTE). This combined with the RS232 problems conspired to partially scramble the switching matrix within the repeaters, so that light took unknown paths. It was only after this error was found, and the delays in the RS232 were understood, that the shore personnel were able to correctly configure the system. With the results of the various JBOX and test connector configurations, a final fiber configuration was arrived at and implemented in the final JBOX deployment. As a side benefit one fiber pair that had previously thought to be broken was found to be working (available for future expansion).

Sensors delivering data now are: camera with two lights (CAM), two hydrophones and precision pressure sensor (HEM), two acoustic Doppler profilers, a temperature/conductivity sensor, and another light (on the observatory frame connected to the µ SEM). The thermistor array/acoustic modem (TAAM) mooring is partially functional, with the 10 thermistors recording data internally using batteries. Two instruments have suffered ground faults/shorts to seawater: the acoustic modem (at the top of the TAAM mooring) and the ALOHA-MARS node with two CTDs and a fluorometer.

V. INITIAL RESULTS

A spectrogram of low frequency (0.01 – 20 Hz) acoustic data for the time period 10-14 June 2011 is shown in Figure 12. Levels in dB are relative to the mean levels measured by the proof module between February 2007 and October 2008. Known earthquake events are noted on the figure. Broadband and tonal ship sounds are evident around 10 Hz. Marine mammals (blue or fin whales) are evident on 14 June at about 16 Hz. It is expected that low frequency acoustic data from the current HEM will be used to continue and expand the studies of wave-wave interaction and ultra-gravity waves [11,17]

Figure 13 shows one view from the camera, looking at the OBS using the single light. During deployment several fish of several species were observed (one ~0.5 m), as were shrimp-like organisms, a sea urchin, and ever present marine snow. Long meandering trails in the bottom made by burrowing organisms were evident in much of the *Jason* video. With the ACO camera and adequate lighting, many opportunities exist for observing and documenting this deep-sea fauna.

Preliminary data from the ADP and CT on the observatory frame are shown in Figure 14. Velocity, temperature, salinity, density, and pressure signals are intriguing all showing relatively large, near simultaneous but intermittent variability. When the thermistor array data is recovered, it will be very interesting to merge the data sets to better understand the connections between the very-near bottom and higher-up, presumably larger scale structure in the abyssal ocean [7-9].

Work is continuing to make all the data easily available. Please see the project web site for the latest updates: www.soest.hawaii.edu/ALOHA. For the conventional sensors, we are using the Software infrastructure and application for MOOS (SIAM) developed at the Monterey Bay Aquarium Research Institute (MBARI) as a framework for interfacing with the sensors, and then using the Shore-side Data System (SSDS) for archiving the data. We are currently working on making the acoustic and video data assessable.

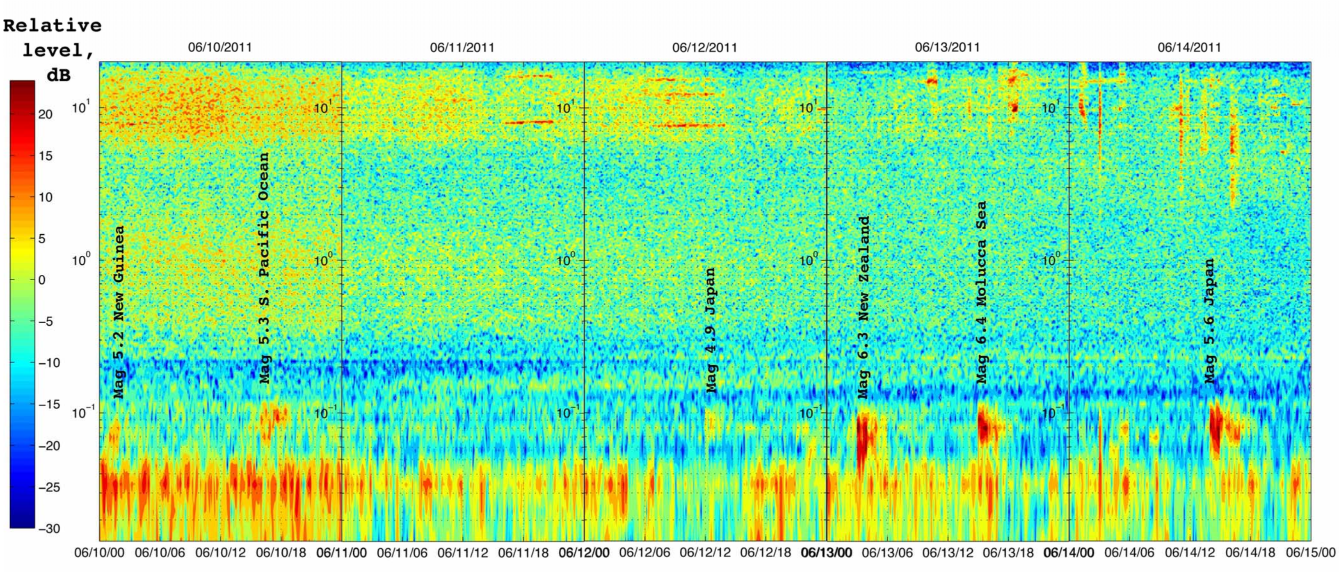

Figure 12. Spectrogram of acoustic data, 0.01 Hz to 20 Hz over 5 days. dB relative to long term mean.

Figure 13. Observatory frame as seen by the camera. Illumination is from the single light on the OBS.

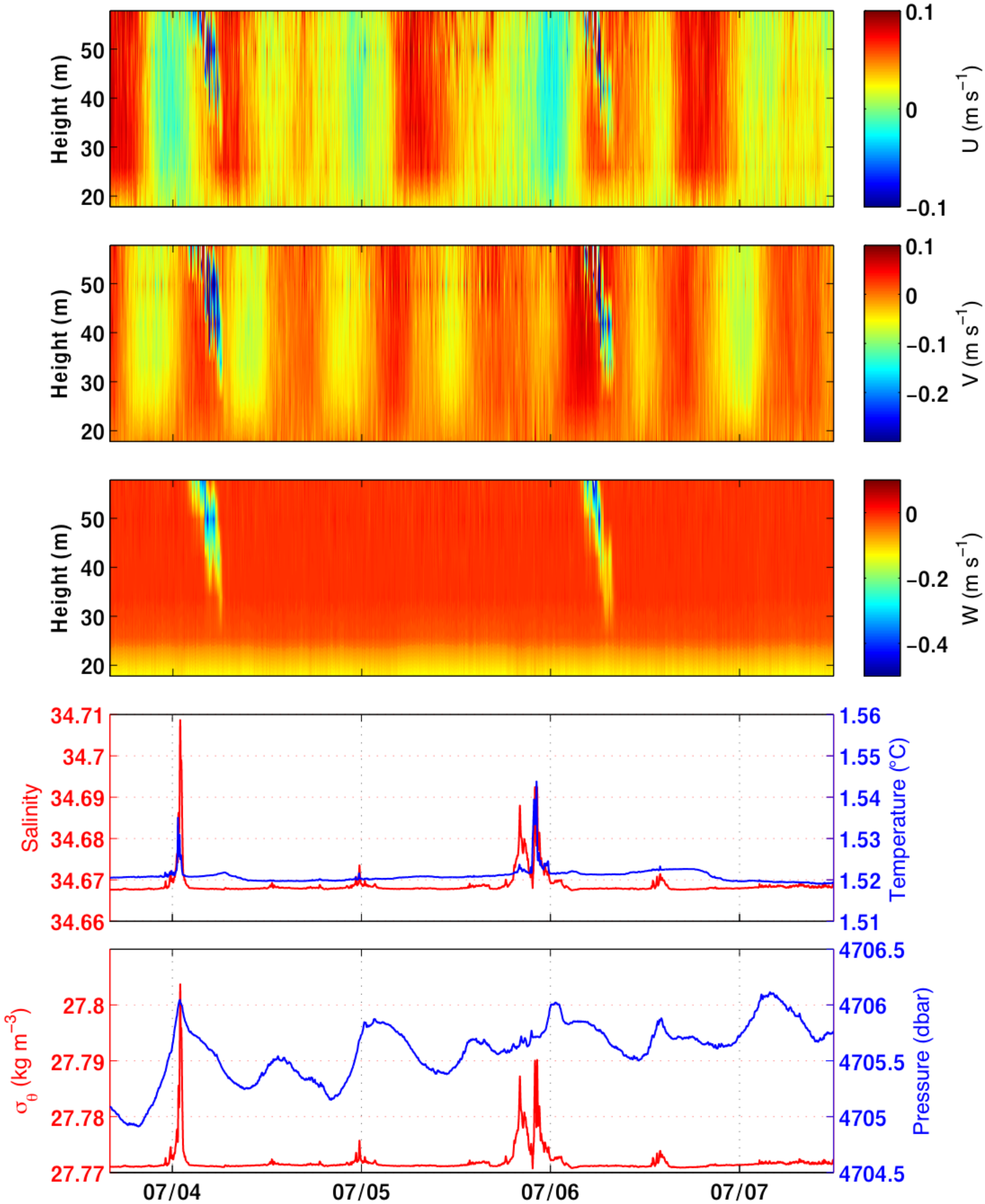

Figure 14. Preliminary ADP and CT data.

VI. CONCLUDING REMARKS

The ACO will extend observational capabilities at the long-running Hawaii Ocean Time-series site, Station ALOHA. Sensors now active provide live video of the surrounding seafloor, sound from local and distant sources, and measure currents, pressure, temperature, and salinity. Spare slots are available to plug in additional sensors and experiments. The capability exists to increase the bandwidth and power available on the seafloor a factor of 4 and 2, respectively.

A sampling of research topics enabled by the ACO include:

- As shown in [11,17], understanding of surface ultra-gravity waves (wavelengths 1 cm to 1 m) is surprisingly limited, though it is suspected that significant air-sea fluxes occur at these scales. The ALOHA Observatory is uniquely suited to host an experiment to study this from space through the air-sea interface to the seafloor.
- By monitoring the flux of detritus to the seafloor, feeding activities of megafaunal deposit feeders and scavengers, and bioturbation rates and patterns, one can better understand links between the shallow and abyssal ocean.
- Recent data is supporting that hypothesis that cold overflow events are generating mixing events [9]. The data above show anomalously warm events. Long-time series of abyssal deep ocean flow and mixing events are needed to elucidate the causes and effects of this turbulence.

These topics will require extending the spatial sampling footprint using fixed and mobile platforms, e.g., full water column profiling moorings, acoustics, autonomous moorings and bottom instruments, and autonomous undersea vehicles.

The sustained, continuous recording of ocean conditions will improve understanding of ocean acoustics, circulation, chemistry and ecosystem behavior, including the testing of ideas and numerical models. The deep ocean is a long-term integrator of surface climate changes, but reading that record previously has been limited by infrastructure constraints and obscured by short-term variations. ACO is a new tool for oceanographers to sample the abyss and the ocean above.

ACKNOWLEDGMENT

We thank the many people who have made the ALOHA Cabled Observatory possible. The success of this deployment was due to support provided by Capt. Rick Mayer and the crew of the R/V *Kilo Moana* and the *Jason* team led by Matthew Heintz. ACO was designed and built by Dave Harris, Jim Jolly, Jim Babinec, Mario Willimason and other staff of the SOEST Engineering Support Facility, along with Mark Tremblay, retired AT&T engineer. Grant Blackinton has recently served as project engineer with Jefrey Snyder, Kimball Millikan and John Yeh assisting. Network communications were designed and implemented by Brian Chee, Chris Zane, Ross Ishida, Pat Townsend and Sharon Stahl. Key data systems were provided by the Monterey Bay Aquarium Research Institute, along with those developed in-house by Jolly and Fernando Santiago-Mandujano.

This material is based on work funded by the National Science Foundation (Grants OCE 0216164, 0652430 and 0939570) and the School of Ocean and Earth Science and Technology, University of Hawaii at Manoa.

REFERENCES

[1] Barnes, C. R., M. Best, L. Pautet and B. Pirenne, Understanding Eearth-ocean processes using realtime data from NEPTUNE, Canada's widely distributred sensor networks, northeast Pacific, Geosciences Canada, 38, 21-30, 2011.

[2] Kawaguchi, K., S. Kaneko, T. Nishida, T. Nishida, and T. Komine, Construction of Real-time Seafloor Observatory for Earthquakes and Tsunami Monitoring, in *Seafloor Observatories: A new vision of the Earth from the Abyss*, Eds. P. Favali, L. Beranzoli and A. De Santis, Springer/Praxis Publishing, in press, 2011.

[3] Butler, R., A.D. Chave, F.K. Duennebier, D.R. Yoerger, R. Petitt, D. Harris, F.B. Wooding, A.D. Bowen, J. Bailey, J. Jolly, E. Hobart, J.A. Hildebrand, and A.H. Dodeman, Hawaii-2 Observatory pioneers opportunities for remote instrumentation in ocean studies, Eos, Transactions, American Geophysical Union, 81 (15), 157, 162-163, 2000.

[4] Karl, D.M. and R. Lukas, The Hawaii Ocean Time-series (HOT) Program: Background, rationale and field implementation. *Deep-Sea Res. II*, 43, 129-156, 1996.

[5] Karl, D.M., J.E. Dore, R. Lukas, A.F. Michaels, N.R. Bates and A. Knap, Building the long-term picture: The U.S. JGOFS time-series programs, *Oceanography*, 14, 6-17, 2001.

[6] Bidigare, R. R., F. Chai, M. R. Landry, R. Lukas, C. C. S. Hannides, S. J. Christensen, D. M. Karl, L. Shi and Y. Chao, Subtropical ocean ecosystem structure changes forced by North Pacific climate variations. *J. Plankton Res*., **31**, 1131-1139, 2009.

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

[8] Lukas, R., F. Santiago-Mandujano, F. Bingham and A. Mantyla, Cold bottom water events observed in the Hawaii Ocean time-series: Implications for vertical mixing. *Deep-Sea Res*. I, 48 (4), 995-1021, 2001.

[9] Alford, M. H., Lukas, B. Howe, A. Pickering, F. Santiago-Mandujano, , Moored observations of episodic abyssal flow and mixing at station ALOHA. *Geophys. Res. Lett.,* accepted, 2011.

[10] Duennebier, F., D. Harris, and J. Jolly, ALOHA Cabled Observatory will Monitor Ocean in Real Time, *Sea Technology*, vol 49,2 51-54, February 2008.

[11] Duennebier, F. K., R. Lukas, E. M. Nosal, J. Aucan and R. Weller, Wind, Waves, and Acoustics Background Levels, *J. Geophys. Res*., submitted, 2011.

[12] Oswald, J.N., T. Norris, W.W.L. Au, and F. Duennebier. Minke whale (Balaenoptera acutorostrata) boings detected at the Station ALOHA Cabled Observatory, *J. Acoustical Soc. Am*, DOI: 10.1121/1.3575555, 129, 3353–3360, 2011.

[13] Harris, D. W., and F. K. Duennebier, Powering Cabled Ocean-Bottom Observatories*, IEEE J. Oceanic Engineering*, 27, 202-211, 2002.

[14] 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.

[15] Howe, B. M., F. K. Duennebier, R. Lukas, The ALOHA Cabled Observatory, in *Seafloor Observatories: A new vision of the Earth from the Abyss*, Eds. P. Favali, L. Beranzoli and A. De Santis, Springer/Praxis Publishing, in press, 2011.

[16] Howe, B. M. , Chao, Y. , Arabshahi, P. , Roy, S. , McGinnis, T. and Gray, A., A Smart Sensor Web for Ocean Observation: Fixed and Mobile Platforms, Integrated Acoustics, Satellites and Predictive Modeling, *Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of*, **3** (4), 507-521, 2010.

[17] Farrell, W. E., and W. Munk, What do deep sea pressure fluctuations tell us about short surface waves?, *Geophys. Res. Letts*., 35, L19605, 2008