Cruise Plan for R/V *Kilo Moana* KM-17-07: ALOHA Cabled Observatory Service and RAP Tomography

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5 June 2017

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1. Introduction

The primary purpose of this NSF and ONR-funded cruise on the R/V *Kilo Moana* is to service infrastructure and instrumentation on the ALOHA Cabled Observatory (ACO). ACO is the deepest operating cabled observatory on the planet. Specifically, a new light (LIGHT4) and a basic sensor package with hydrophone (BSP3) will be installed, and three packages will be recovered (BSP1, CAM2, and LIGHT1). The remotely operated vehicle University of Hawaii ROV *Lu'ukai* is essential to performing the required tasks.

A secondary task is to collect acoustic data for the ONR project *Station ALOHA: RAP Tomography* (Reliable Acoustic Path). The associated work will take place during and between ACO ROV operations, and/or on dedicated days. During the time at ALOHA, the ship will transmit using 3.5 kHz echosounder equipment to the ACO hydrophone; this will involve transmitting while on-station at ACO and several circle and radial runs out to 35 km range. Details are in Appendix C.

The cruise is 9 days long, from 0800 Wednesday 7 June – 1500 Thursday 15 June 2017. It is a continuation of the ROV test cruise KM-17-06 (1-7 June). The nominal division between the two cruises will be a personnel transfer the morning of 7 June at Ko Olina, after which the ship will proceed directly to Station ALOHA, 100 km north, to perform the ACO work. If all goes according to this current plan, the work can be done during three ROV dives, approximately 44 hours of bottom time. See Figure 1-1 for a map with nominal cruise lines. Table 1-1 gives coordinates of relevant points.

Figure 1-1 Map of area and nominal cruise lines.

	Depth m	Latitude deg	N minutes	Longitude deg	W minutes	Incremental distance (nmi)
UHMC, Snug Harbor		21	18.937	157	53.186	
Honolulu WP1		21	16	157	54	
Barbers Point WP		21	16	158	09	14
Ka‘ena Ridge WP		21	33	158	20	21
ACO Cable Termination Frame (TF)	4728	22	44.324	158	00.372	75
Station ALOHA		22	45	158	00	1

Table 1-1 Coordinates of waypoints and stations

In this Plan, we first describe the ACO system as it is now installed followed by a description of the new instrumentation to be installed. The ROV system is described, including the navigation system. The ship and deck configuration is described followed by a section on responsibilities. Finally, the operations are described with a timeline (some readers may wish to skip some of the preceding material). An even more detailed step-by-step plan is given in Appendix B. Other appendices have system diagrams and connections, personnel/contacts, berthing, acronyms, and a description of the RAP work.

Information on the previous service cruises (KM-15-16 and KM-14-26) and installation cruise (KM-11-16) can be found in the respective cruise plans and reports, and the Oceans11 paper. See the list of references below and the ACO web site for this and other information including photographs and video, http://aco-ssds.soest.hawaii.edu/index.html. Because the ROV operations are so important for this cruise, this plan is written to emphasize those aspects.

All cruises such as this have some level of risk associated with completing the desired tasks. The most obvious two factors affecting risk here are weather and technical problems. Weather is always a concern. Working with the “one-body” ROV+TMS package and free-falling elevator and packages should let us work in a rougher weather than otherwise and get the work done with just three ROV dives (limited by navigation beacon availability). The risk of technical problems with the ROV have been mitigated with the additional effort put into the system in the last year, since the 16-21 September 2015 cruise that reached 4728 m and plugged in Basic Sensor Package 2 (BSP2).

2. ACO Description

The ACO is an example of a deep ocean observatory system that uses a retired cable. The ACO uses a highly reliable existing transoceanic cable system to provide power and communications bandwidth to a “node” on the seafloor. In the simplest terms, we provide power and communications ports for users to plug into on the seafloor for arbitrary instrumentation. Here we include core instrumentation for scientific measurements of water properties (pressure, temperature, salinity, velocity, optics), video and acoustics, and acoustic communications.

The ACO node and instrumentation were deployed in May-June 2011 (see the KM-11-16 Cruise plan and report, and the Oceans11 article, Howe, et al., 2011). A subsequent service cruise in November 2014 removed a failed secondary node and added CAM2, LIGHT1, and BSP1, Fig 2.1. Then in September 2015 BSP2 was plugged in, but the ROV failed and time ran out before we could connect LIGHT4, and before we could recover BSP1, CAM2 and LIGHT1 which had all failed. Below, recent photographs of the system are shown, followed by older pictures; brief descriptions of various components are given. A plan view line drawing to scale is given in Figure 2-11 of the present system. System block diagrams with the last interconnections are shown in Appendix A (along with the planned configuration). Section 3 addresses new components and an overview of tasks.

Additional photographs and other system documentation can be found on the project wiki web site http://www.soest.hawaii.edu/acowiki/index.php/Main_Page. Also see the ROV *Jason* Virtual Control Van videos for the two cruises (e.g., http://4dgeo.whoi.edu/webdata/virtualvan/html/VV-km1116/index.html).

Figure 2-1 shows an image taken by *Jason* of the seafloor equipment in November 2014; from left to right, CAM2, CAM1, LIGHT1, OBS, and JBOX. The cable termination frame (TF) is to the right (Figure 2-2), and BSP1 farther still to the right (Fig. 2-3). CAM1 is working but the lights have failed, so we will be leaving it in place (though we may move it a little). The stand-alone LIGHT4 is a copy of LIGHT1.

The elevator is basically a stack of flotation with a cage at the top for beacons and recovery lines, an acoustic release, and then a weight below that can be acoustically or with the ROV released.

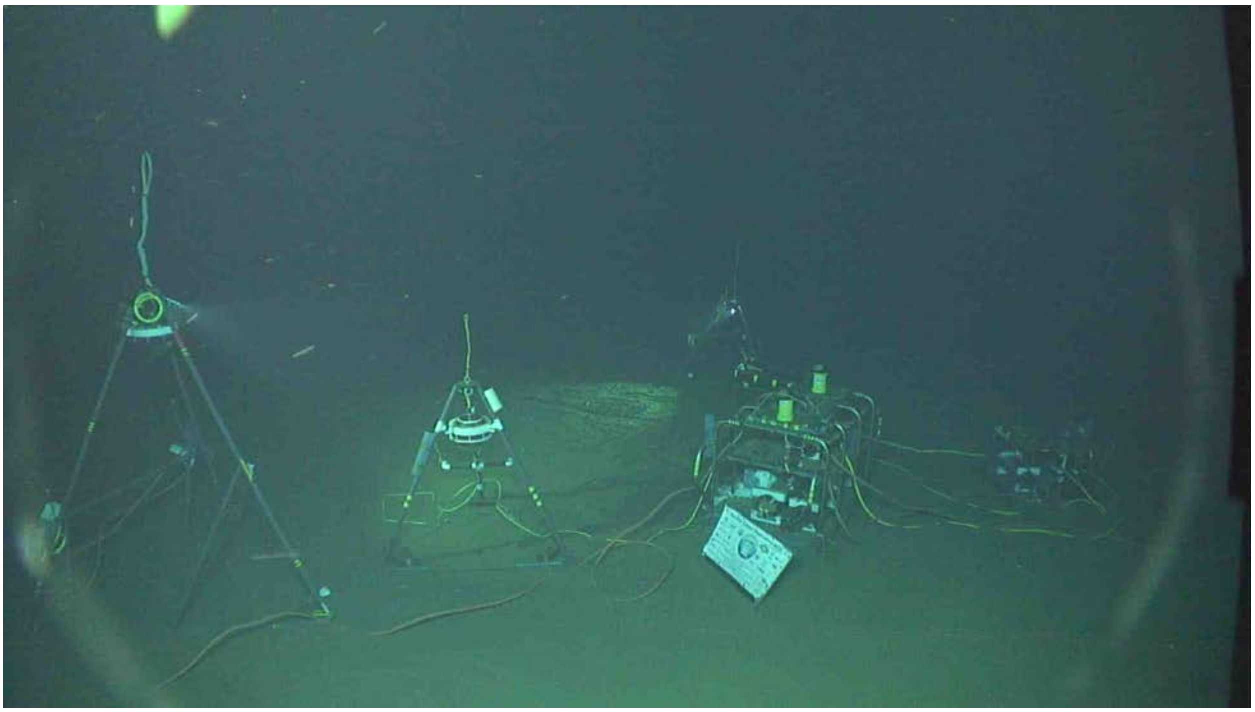


Figure 2-1 Image of system at the end of the November 2014 cruise. The BSP1 is off to the right 18 m.

Figure 2-2 The cable termination frame on 6 June 2011 (bottom)

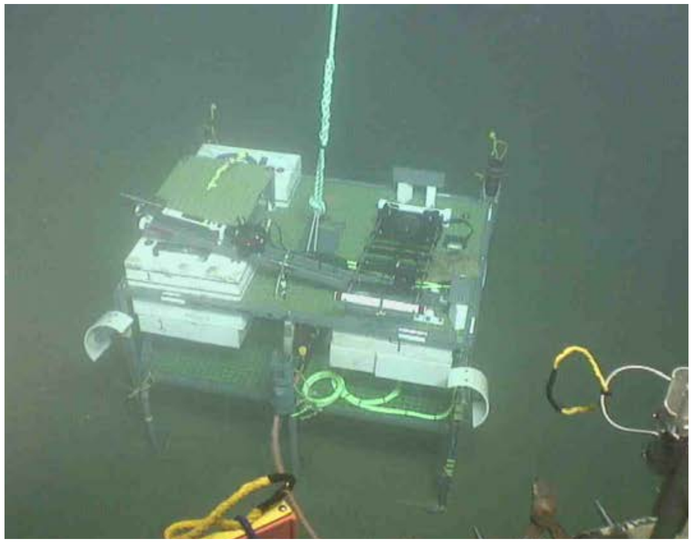


Figure 2-3 ACO Basic Sensor Package 1 (BSP1), just prior to raising masts.

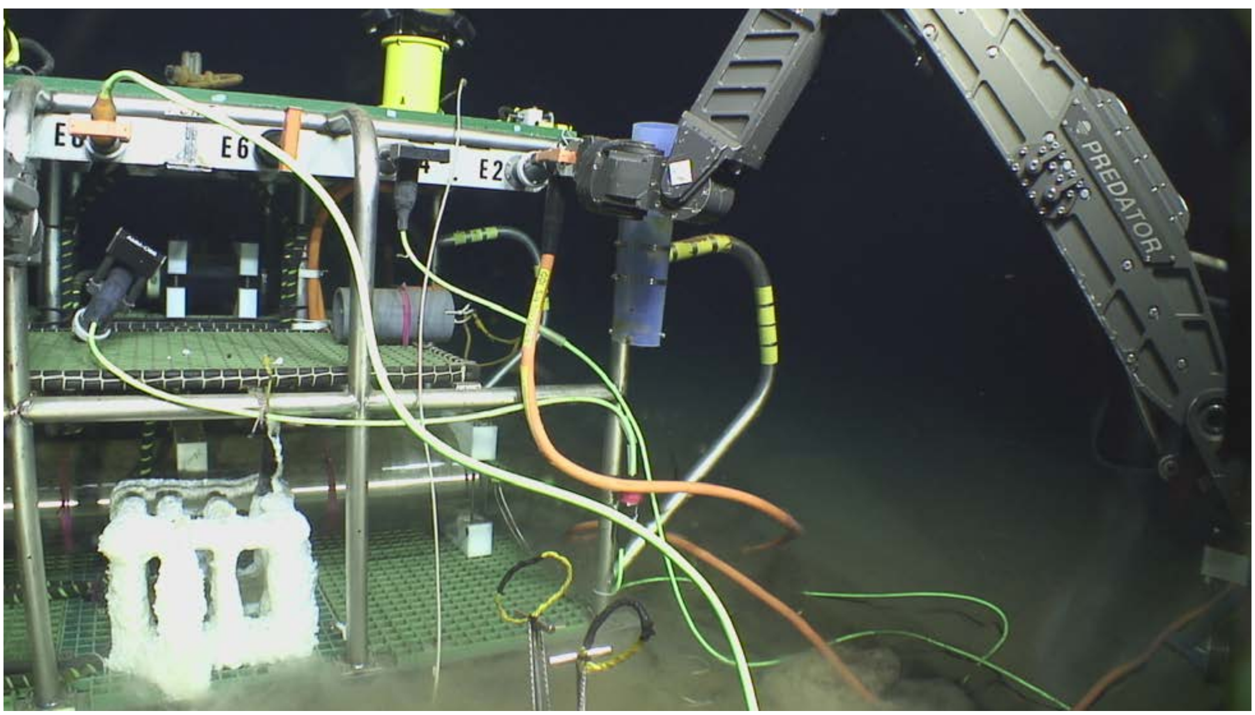


Figure 2-4 Jason plugging in CAM2.

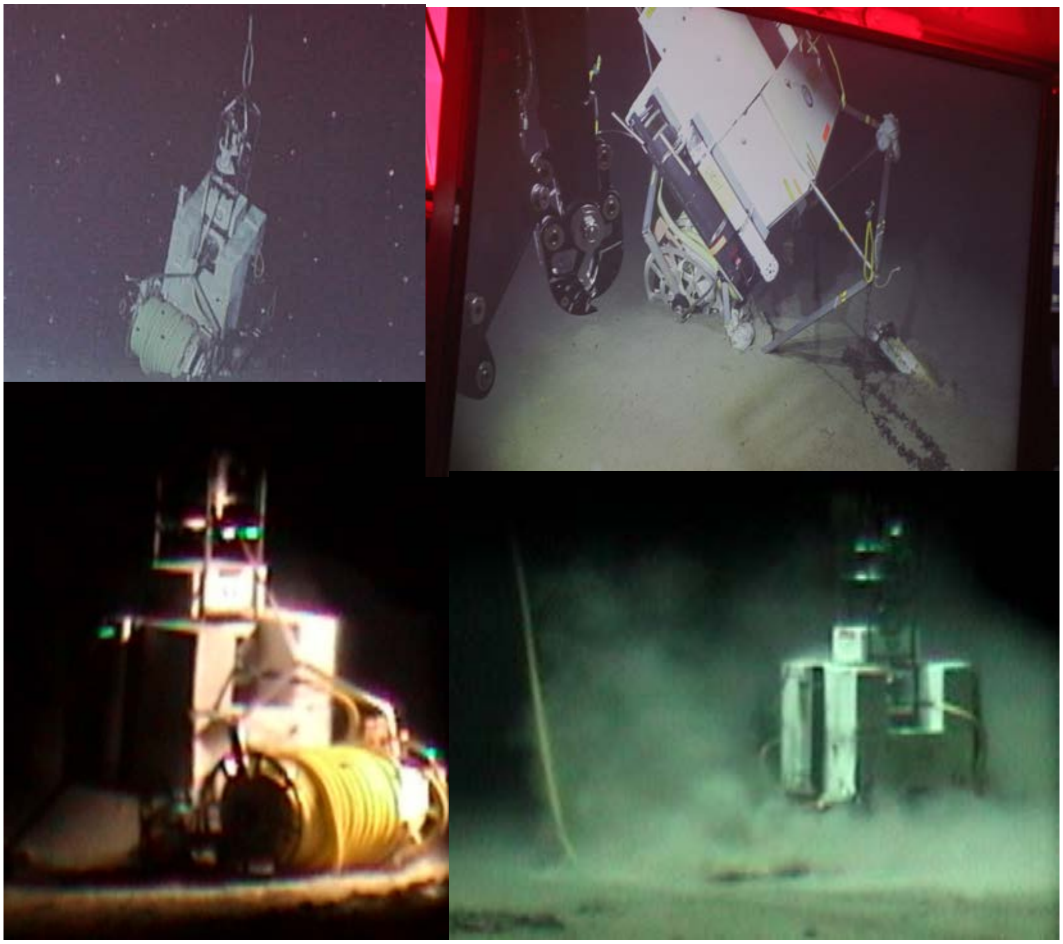


Figure 2-5 ACO Basic Sensor Package2 (BSP2) as viewed by ROV Lu'ukai and CAM1. In the bottom right image, Lu'ukai is above left unspooling the yellow connecting hose.

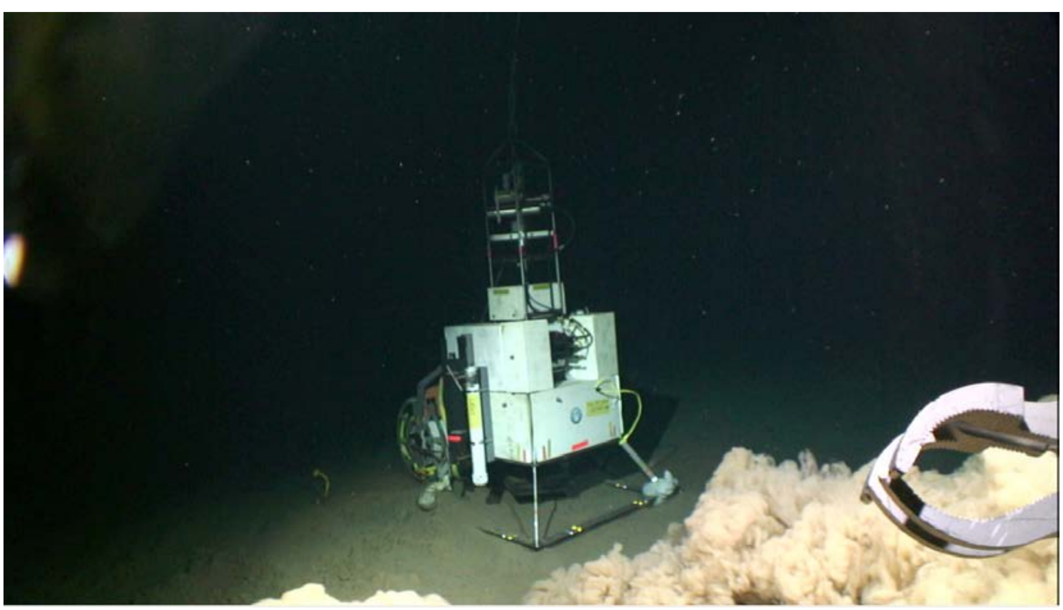


Figure 2-6 BSP2 as viewed by Lu'ukai after it has been leveled with weight bags (right corner of frame).

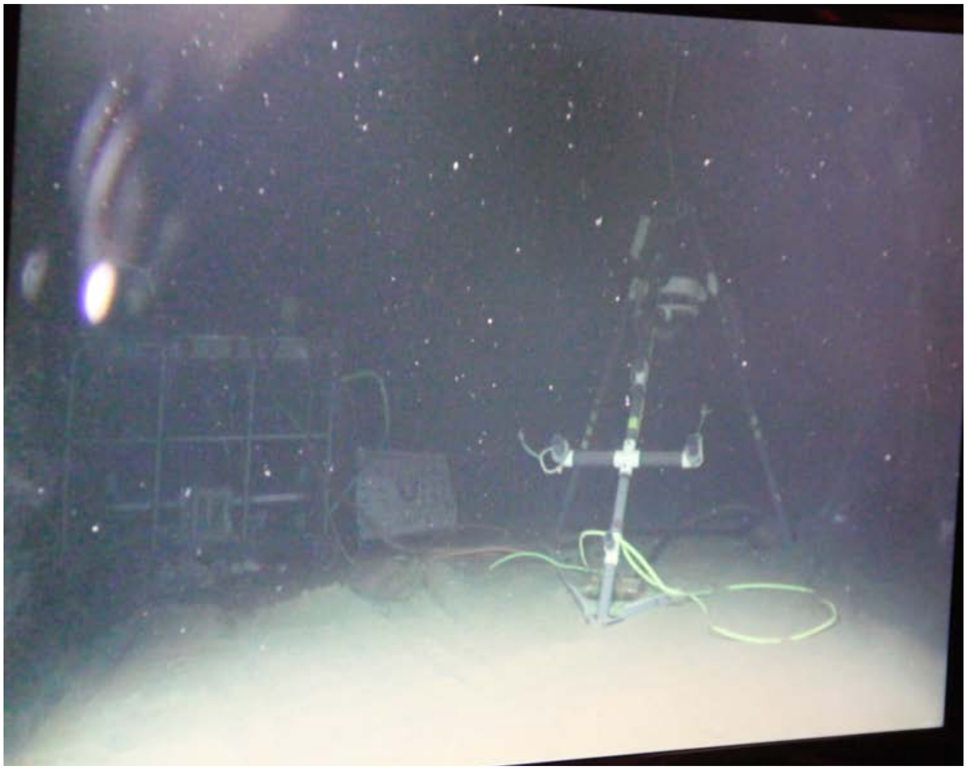


Figure 2-7 From Lu'ukai, the observatory, banner acknowledging organizations who have contributed to ACO, and CAM1.

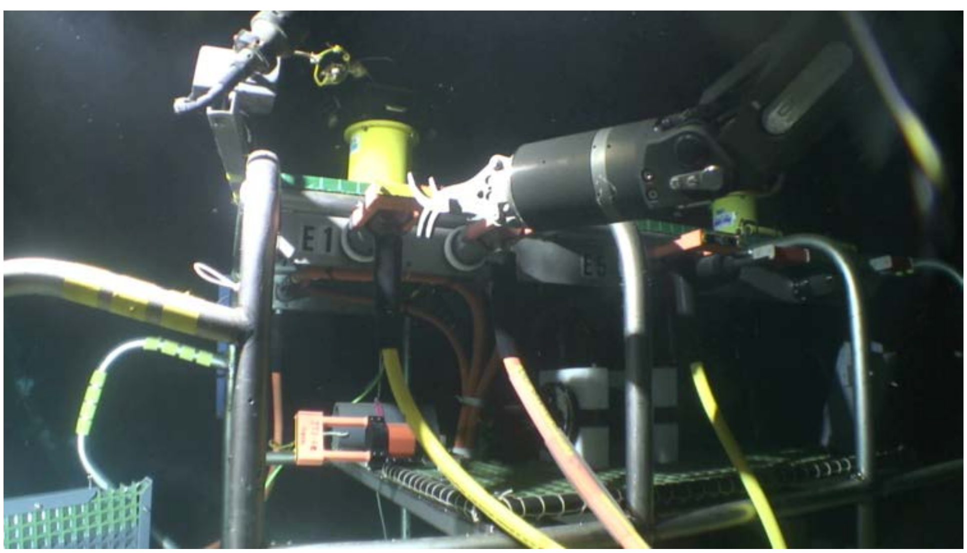


Figure 2-8 Lu'ukai connecting BSP2 to Port E1 on the observatory.

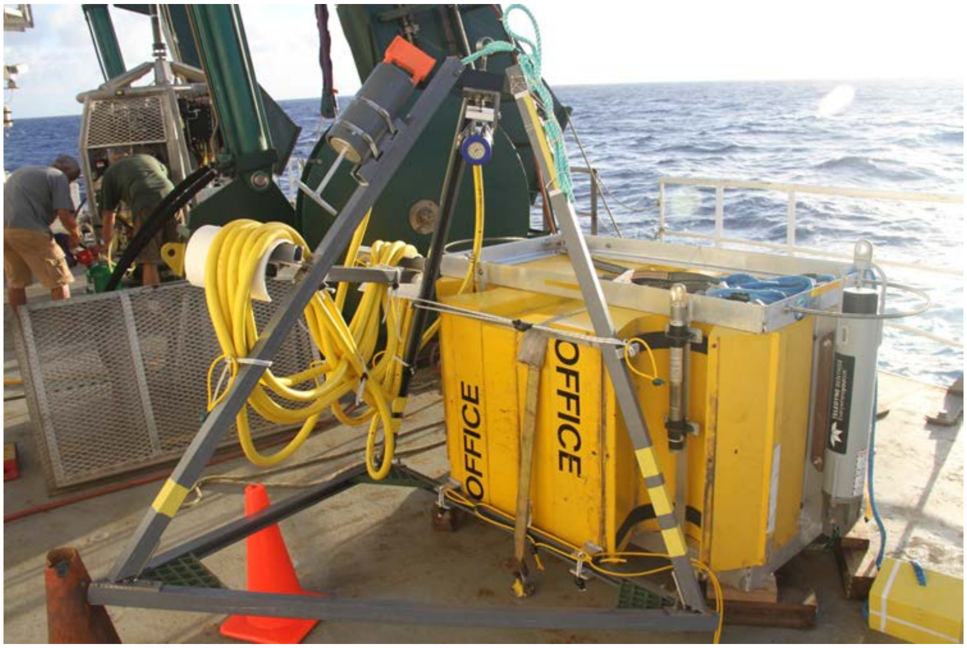


Figure 2-9 ELEVATOR set up with LIGHT 4 for deployment. Later, LIGHT4 was dropped by itself.

Figure 2-10 LIGHT4 on its side at 0144 UTC on 21 September 2015.

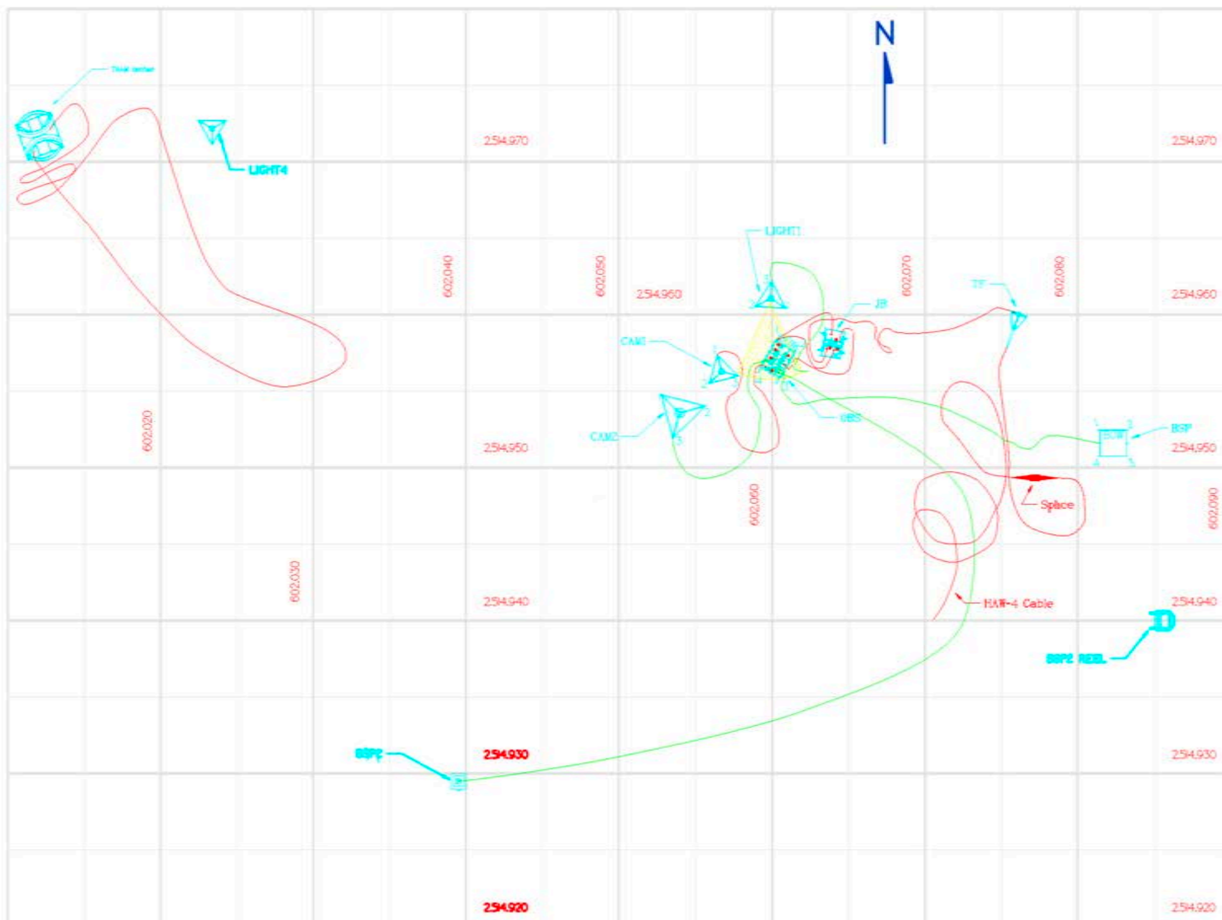


Figure 2-11 Present ACO seafloor configuration.

To provide familiarity for the ROV pilots, more detailed description and earlier photographs of the equipment are given next.

The ACO cable termination is connected to the junction box (JBOX) with an ODI hybrid optical-fiber/electrical hose assembly. The JBOX provides the fiber-to-electrical 100 Mb/s Ethernet and generates a precise pulse-per-second referenced to GPS on shore using IEEE-1588v2-PTP precise time protocol. On the JBOX frame is the hydrophone experiment module (HEM) with two hydrophones and a pressure sensor, Figure 2-12.

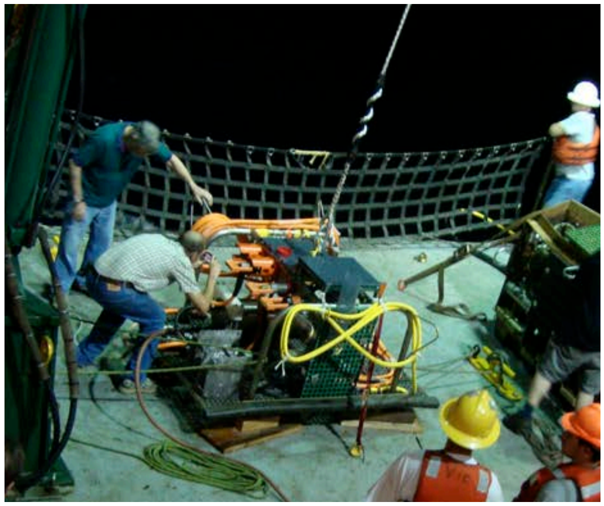
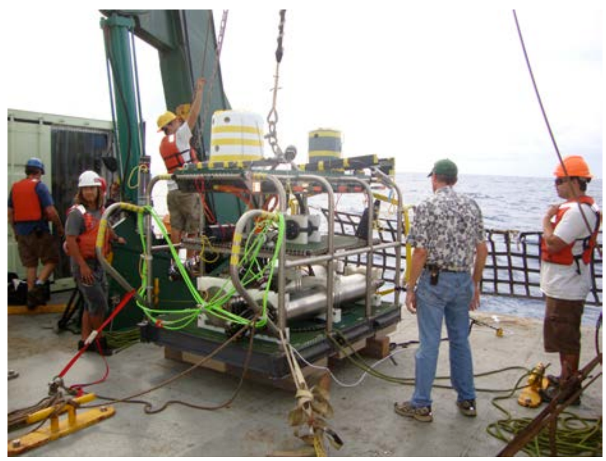


Figure 2-12 ACO JBOX.

The observatory (OBS) is connected to the JBOX, Figure 2-13. The OBS converts the dc current on the cable to 48 V and 400 V, and distributes this, the Ethernet, and timing signals to eight user ports. On the observatory are two acoustic Doppler profilers (ADPs), a temperature/conductivity instrument (CT), and a light, that are connected to one "micro science experiment module" (μSEM) that is in turn (hard) connected to one OBS port, E6. Note the orientation guides: yellow tape on corners (1-4; 1 is port bow, 2 is starboard bow, …), and port numbers; see also Appendix A for a schematic of this including instrument port assignments. Deck pictures show the CTD and light in stowed positions; on the seafloor they have been rotated 180 degrees, so as to hang outboard of the OBS. Note the seawater return/ground plates on the bottom of the Observatory, port side. Also note the pin-protecting dummy at the stern on the middle deck; there is also one in the E6 position on the port quarter.



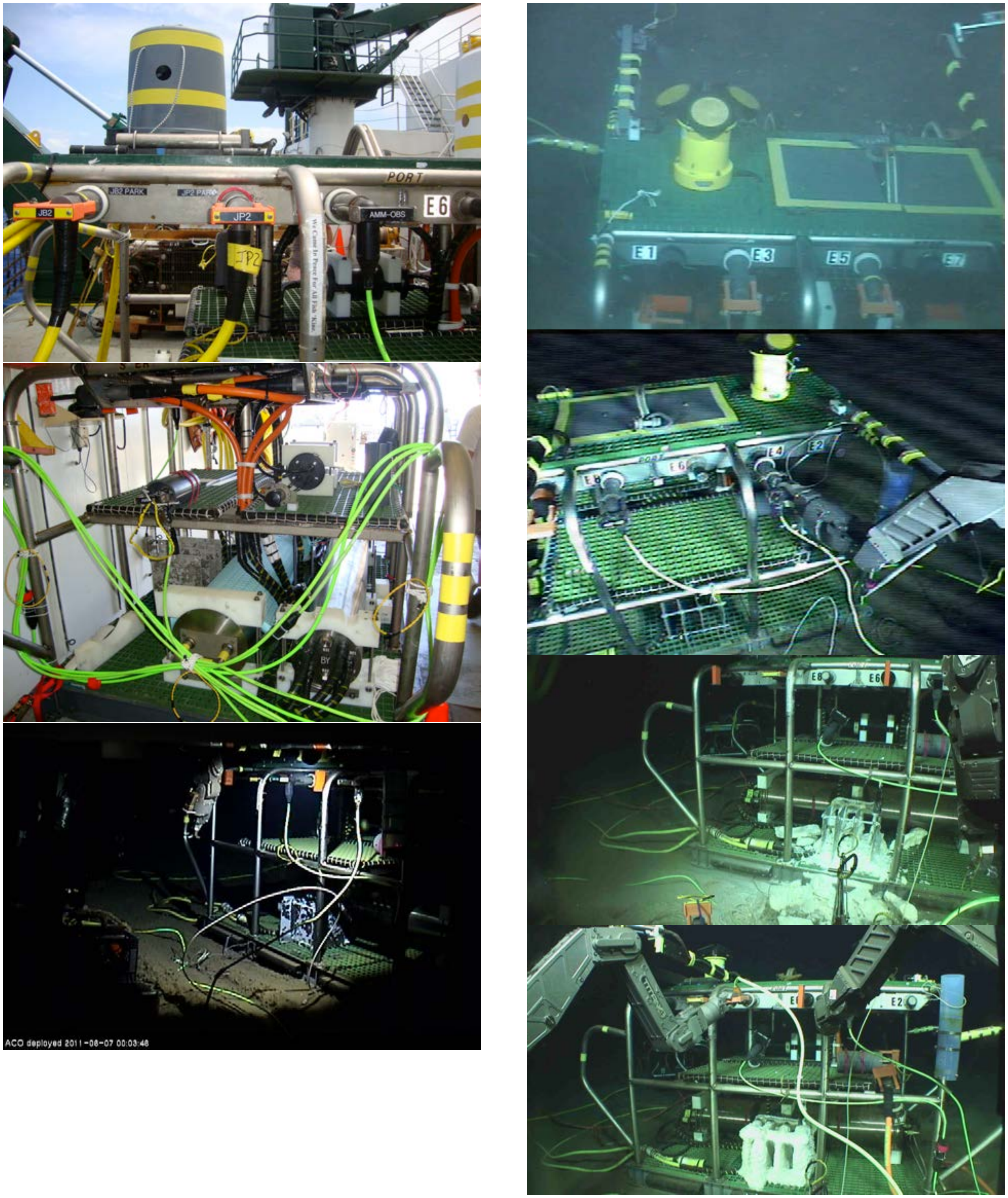


Figure 2-13 OBS frame (on deck and seafloor).

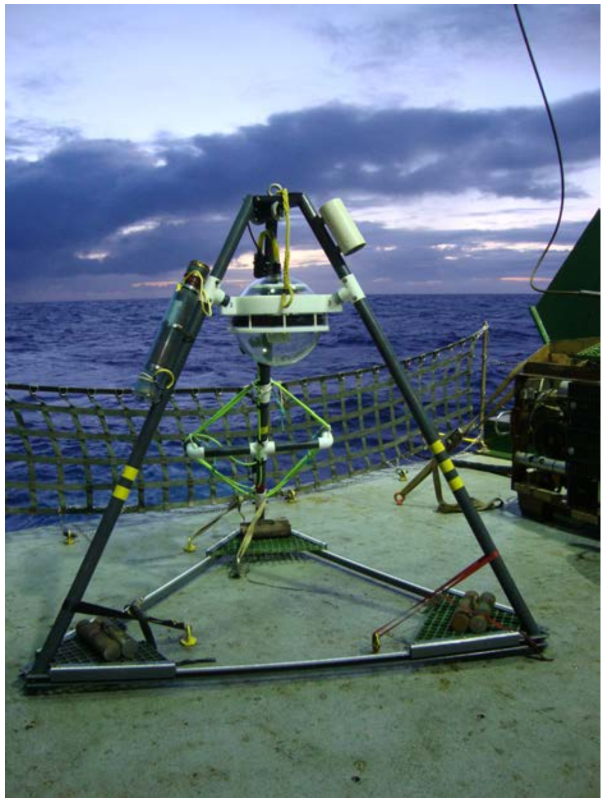


Figure 2-14 CAM1, deployed June 2011.

The TAAM anchor sits 50 m off to the west. The mooring was recovered in December 2011, and the two ODI connectors and pin-protecting dummies recovered in 2014. We will use the TAAM anchor as a location for leftover weights, and other miscellaneous items being left on the bottom.

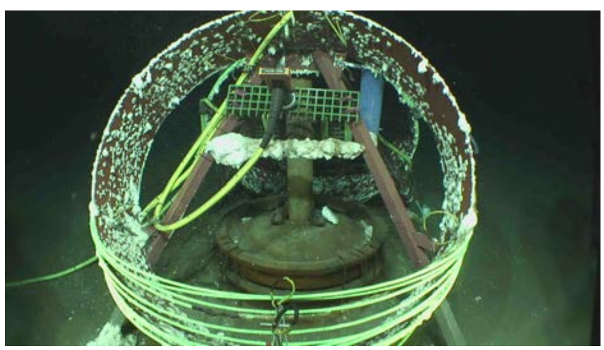


Figure 2-15 TAAM anchor 50 m to the west (connector was retrieved in November 2014).

The BSP1 is made up of a Science Instrument Interface Module (SIIM, from APL-UW), several science instruments, and a frame with syntactic foam buoyancy and ballast weights and provision for carrying navigation beacons (Figure 2-17). The BSP1 is connected to the OBS via a 20 m ODI pressure balanced oil-filled (PBOF) hose with a 12-pin flying connector, and a corresponding dry mate connector to the SIIM.

The SIIM aggregates multiple instruments so that only one standard 12-pin connect or is required to connect to the Observatory (OBS) or similar. The SIIM brings together the following sensors: Seabird conductivity, temperature, depth (pressure) and oxygen pumped (CTDO2), SBE- 37 SMP ODO; RBRduo bottom pressure recorder (BPR); WetLabs fluorometer/turbidity optical sensor, FLNTU; Woods Hole Oceanographic Institution (WHOI) acoustic micro-modem; and Teledyne RDI broadband 150 kHz acoustic Doppler current profiler (ADCP).

The corners of the BSP1 are numbered and marked with yellow tape (ADCP is at the bow): port bow, 1 tape; starboard bow 2 tapes; starboard stern 3 tapes; port stern 4 tapes. This is the same convention as with the OBS.

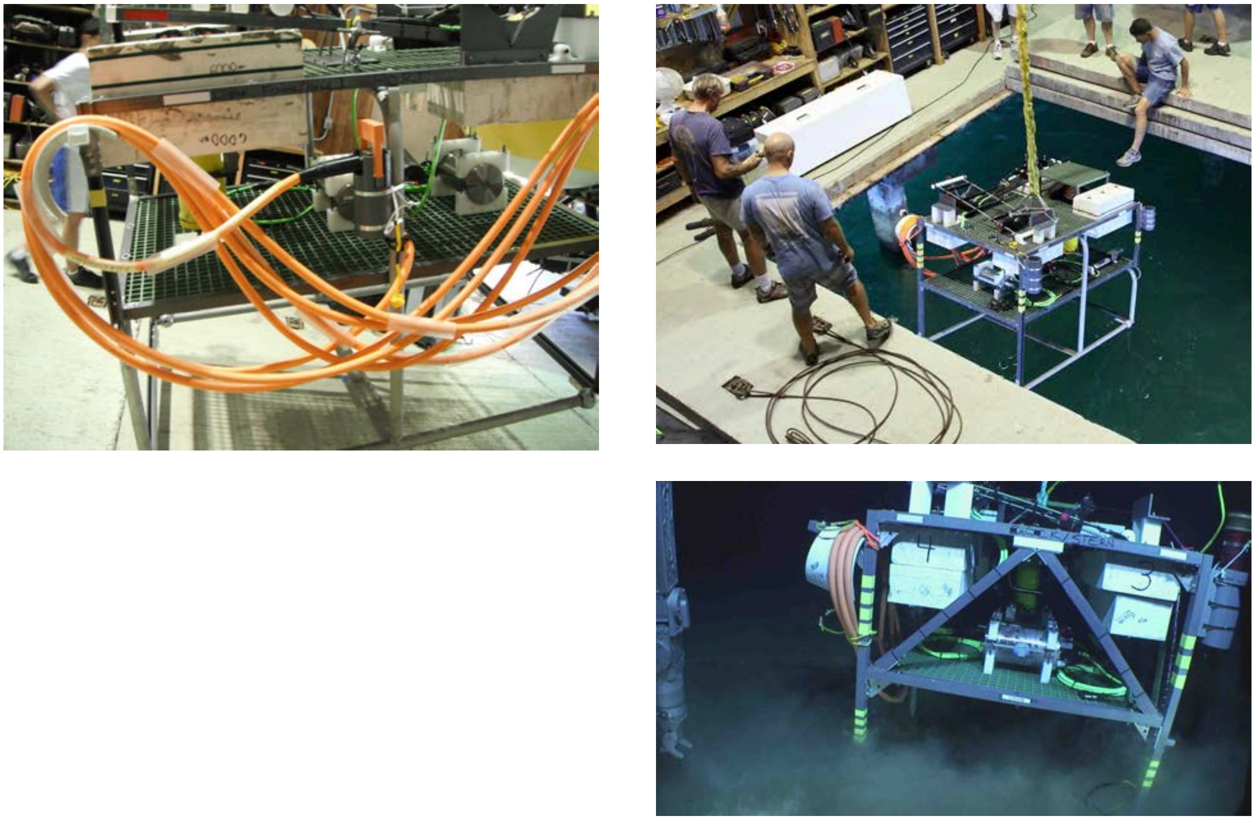
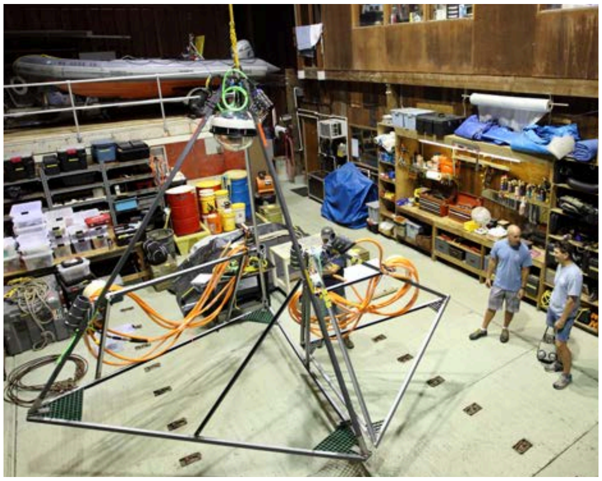


Figure 2-16 BSP1 at Makai Pier and on bottom.

The CAM2 has a similar configuration as the current CAM1, i.e., an AXIS Internet surveillance camera inside a Nautilus polished glass sphere with two lights and a hydrophone, Figures 2-17.and 2-18.

The camera is ~8-ft (2.4 m) off the bottom. The length of a side on the bottom is 10 ft (3.0 m) and the length of the slant leg is 12 ft (3.6 m). The top of the frame is 11 ft 8 inches (3.6 m) high. The frame is made from the same fiberglass uni-strut and grating as the BSP1. Stainless steel brackets and fasteners are used where necessary.



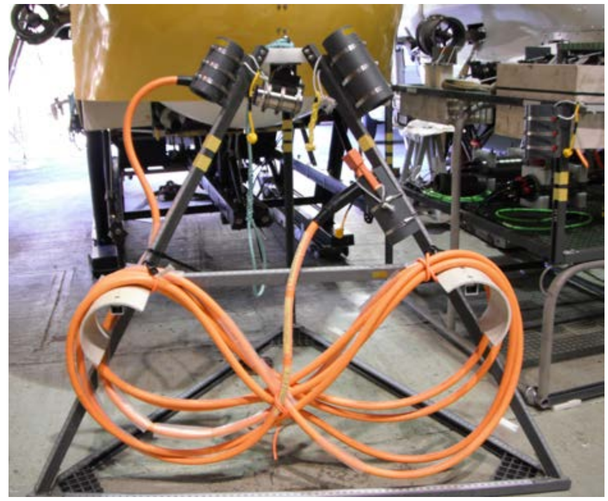


Figure 2-17 CAM2+LIGHT1, and LIGHT1 – stand alone (with holsters)

Figure 2-18 BSP1, LIGHT1 and CAM2 on seafloor at Makai Pier.

The BSP2 is made up of a Science Instrument Interface Module (SIIM, from APL-UW), several science instruments, and a frame with syntactic foam buoyancy and ballast weights and provision for carrying navigation beacons (Figure 2-19). The BSP2 is connected to the OBS via a 50 m pressure balanced oil-filled (PBOF) hose with a 12-pin flying connector, and a corresponding dry mate connector to the SIIM. This SIIM has been modified so it can plug into a 400 V port if necessary.

The SIIM aggregates multiple instruments so that only one standard 12-pin connect or is required to connect to the Observatory (OBS) or similar. The SIIM brings together the following sensors: Seabird conductivity, temperature, depth (pressure) and oxygen pumped (CTDO2), SBE-

52/43MP; Paroscientific nano-resolution pressure sensor; and WetLabs fluorometer/turbidity optical sensor (FLNTU).

The stand-alone LIGHT4 is a copy of LIGHT1 (see Figure 2-17).

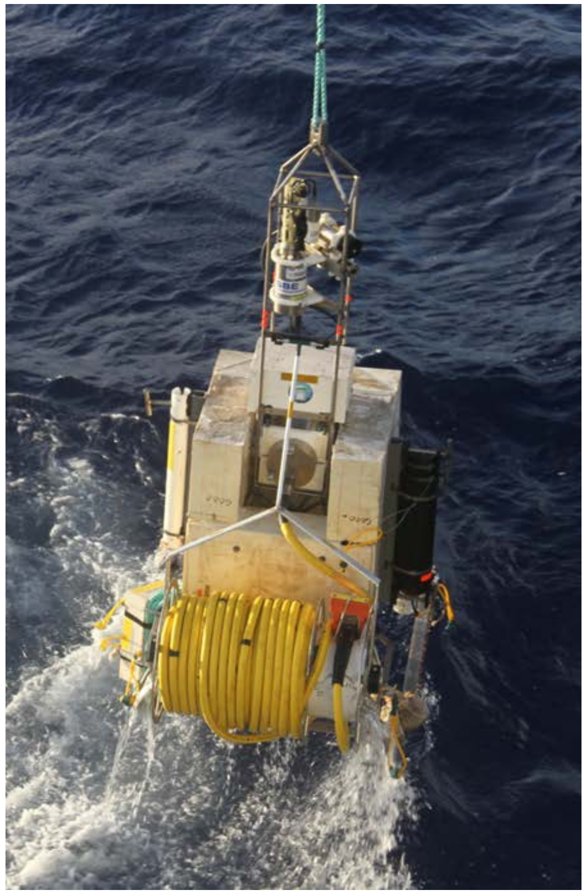


Figure 2-19 BSP2 with cable reel holding 50 m of hose.

3. New ACO Equipment and Overview

Some equipment will be recovered and new equipment installed so that we end with a system layout as shown in Figure 3-1. A preview of tasks is useful here (more detail in Section 10 below). If all goes according to plan, three ROV dives are required (limited by number of ROV navigation beacons).

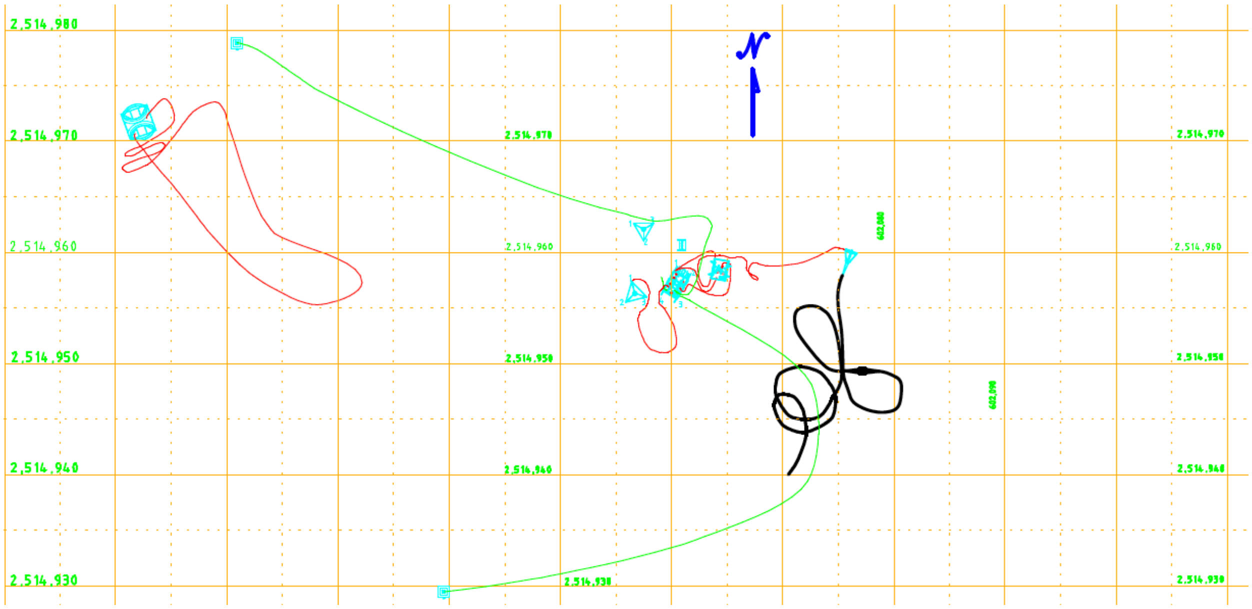


Figure 3-1 ACO Layout intended at end of cruise 2017 [NB – real figure to come].

After deploying and reaching the bottom, the LIGHT4 already on the seafloor will be plugged in (replacing LIGHT1). The ROV will return to the surface carrying the navigation beacon to be used on BSP3 (after new batteries installed). The BSP3 (just a single hydrophone) will be free-falled and then connected (ending at the NW). The ROV will again carry up the beacon to be used on the ELEVATOR.

After free-falling the ELEVATOR and diving the ROV, the three packages to be recovered, LIGHT1, CAM2, and BSP1, will be attached to the ELEVATOR recovery line. Housekeeping will be done at this point (e.g., adjusting LIGHT4). Finally, the ELEVATOR with its packages will be released and recovered, while the ROV is ascending; it will stay submerged to complete housekeeping tasks.

The BSP3 is a Oceansonics icListen HF hydrophone (serial number 1391), and a frame with syntactic foam buoyancy and ballast weights and provision for carrying navigation beacons (Figure 3-2). The BSP3 is connected to the OBS via a 50 m pressure balanced oil-filled (PBOF) hose with a 12-pin flying connector, and a corresponding dry mate connector to the BSP3, via a PBOF oil-filled jumper. Within the jumper is a 48V-24V converter.

The elevator is basically a stack of flotation with beacons and recovery lines, an acoustic release, and a weight below that can be acoustically or with the ROV released (Figure 3-3).

Lastly, a "SonarBell" will be deployed. It is a 200-mm plastic sphere (filled with pressure balanced fluid) passive sonar target tuned for the ROV scanning sonar (325 kHz). It will be on a 2-m mooring, deployed from the ROV basket at the cable termination.

Figure 3-2 BSP3 with cable reel holding 50 m of hose.

Figure 3-3 Elevator with line basket in front left canister.

4. ROV and TMS

ROV *Lu`ukai* is a two-body ROV system (Figure 4-1). A 0.681-inch electro-optic-mechanical (EOM) cable delivers electrical power and commands from the ship through the TMS and then to the ROV; both return data and live video imagery. The TMS serves as a dock for the ROV facilitating launch and recovery. When the ROV is swimming free of the TMS loosely tethered, the ROV is then decoupled from the movements (heave primarily) of the ship. While the tether is 100 m long, operationally, making effective use of this length requires further testing/practice. The TMS provides 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 is used as the main umbilical to TMS.

Figure 4-1 TMS and ROV.

5. Navigation

Lu'ukai will navigate in several ways. In addition to video, a scanning sonar will be used to detect targets/packages to a range of ~50 m. For large area coverage, the UH Sonardyne ultra-short-baseline (USBL) system will be used. The USBL transducer head will be installed on the retractable stem on the port side that can lower the sensor head 6-ft below the bottom of the hull. It will measure range and solid angle to beacons on the TMS and ROV, and our packages. The azimuthal orientation will have already been calibrated on the preceding cruise.

The ultra-short baseline transducer is a Sonardyne Marksman LUSBL Model 8023 with a 50° wide downward looking beam. The accuracy specification is 0.27 percent 1 Drms Slant Range, i.e., 63 per cent of fixes lie within 13.5-meter radius in 5,000 meters water depth. The transponder beacon is shown in Figure 5-3. The two beacons on the TMS and ROV will be configured as responders (triggered with an electrical signal from the deck unit). We are borrowing from MBARI one Sonardyne beacon to use on the ROV and TMS leaving one UH beacon to time share on the elevator and the BSP3 (to be recovered from LIGHT4 and re-batteried). Absolute geographical position is provided by the ship's POS-MV system using Fugro GPS with decimeter accuracy.

Figure 5-1 USBL Wideband Mini Transponder (WMT) – 7000 m

6. Deck Layout

When on deck, *Lu`ukai* will sit on the centerline under the A-frame. The tool van and the ROV control van will sit on the O1 level, port side. The motor-motor generator will be placed on the O1 level, starboard side. The Connector Test Frame will be on the starboard quarter for use in the harbor. The ship's crane will be used to deploy this. The STU will be put in line between the traction winch and the A-frame, immediately adjacent to the bulkhead of the winch room. The STU weights 13,000 lb and the base plate 3,500 lb. The ELEVATOR will be placed on the aft port quarter for deployment with the crane, along with BSP3. The latter will be connected via the oil-filled hose to the bench node in Lab2 for testing prior to launch.

Interior space is allocated as follows: The PI and the ROV crew share Lab2. ROV supplies will be in HydroLab. Hydraulic oil supplies will be in the WetLab. Personnel are free to use the rest of the lab space for personal computers, etc.

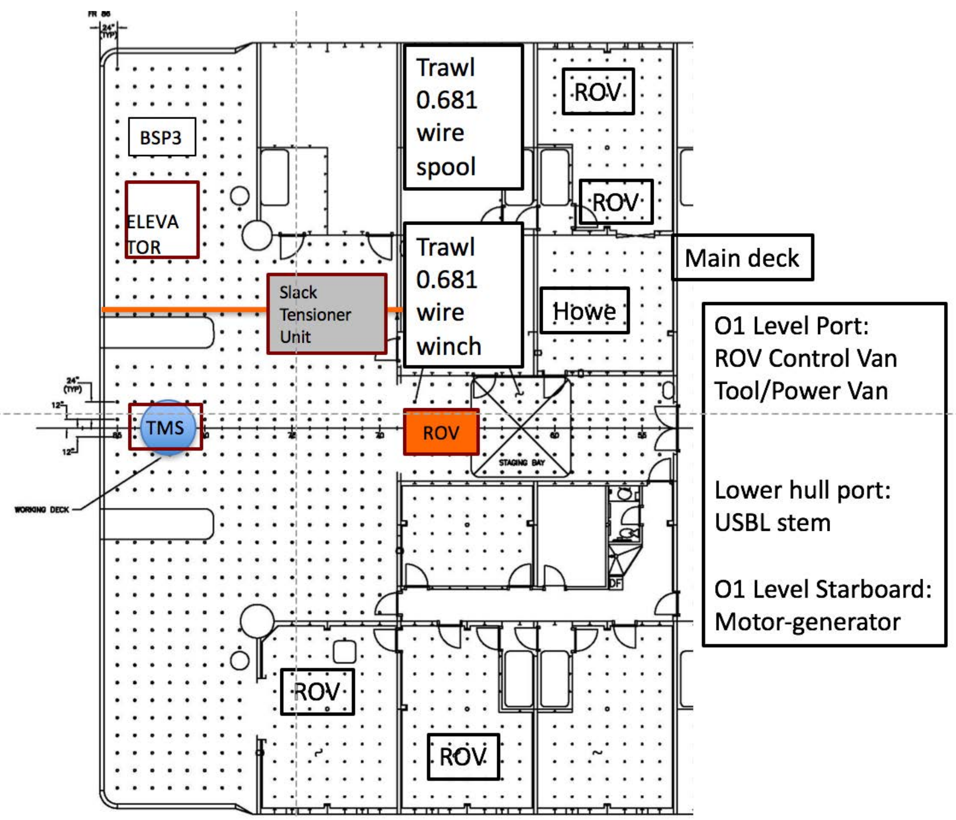


Figure 6-1 Main deck layout

7. Mobilization

The ROV with all its gear will already be on the ship, after about 6 days at sea. Similarly, all the ACO gear will be on the ship.

8. Responsibilities

The ACO science team is responsible for all the ACO packages, testing and preparing these for deployment, and providing science direction to the ROV crew during operations.

Good communications with the shore party will be essential. ACO will bring one Iridium phone (from Seaglider Lab). In addition to HiSeasNet Internet, the ship/OTG will provide a dedicated Fleet Broadband satellite Internet connection in the ROV van for real time email and chat with the ACO shore party. ACO will have a laptop in the control van for this purpose.

The ROV team will operate the ROV, and be in charge of the deck during all operations that involve their equipment.

ACO/OTG will be responsible for deploying the free-falling ELEVATOR and BSP3 and recovering the ELEVATOR with LIGHT1, CAM2, and BSP1.

ACO will supply pin-protecting dummies for ODI connectors (2 available), with ROV mating provision (i.e., T-Handle).

ACO will provide a "dumb" dummy/resistive load port test tool.

ROV will provide cutting tools, i.e., sharp knives and garden shears for line, bungies, tie wraps, in the "tool box" in the basket.

OTG will provide one USBL beacon on loan from MBARI for the ROV (or TMS), so that each vehicle has a beacon. One beacon on LIGHT4 will be recovered and new batteries installed for subsequent use.

ACO will provide cleaning/scraping/brushing tools for cleaning the precipitate crust on the seawater return (SWR) on the OBS.

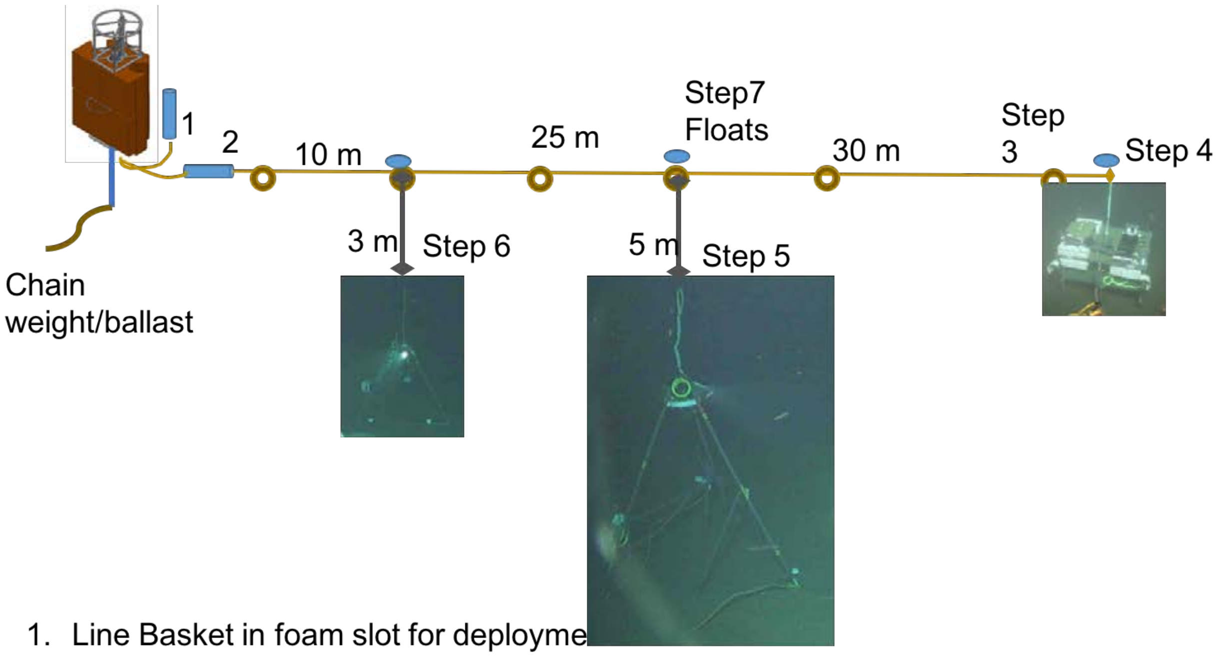
The ship will operate much of the time in dynamic positioning. This entire system must be checked out before this cruise and it must be fully operational with all backup and redundant systems tested and operational.

The ship and OTG will provide sub-bottom echosounders (3.5 kHz and 12 kHz), acoustic Doppler current profiler data/plots (using 38 kHz and 300 kHz instruments), two air tuggers, and pallet jack.

9. Operations and timeline

Some equipment will be recovered and the new equipment installed so that we end with the system layout shown in Figure 3-1. Three ROV dives are required. Initially LIGHT4 will be plugged in and its beacon recovered. This beacon will be deployed on BSP3. After the latter is connected, the beacon will then be brought back up to attached to the ELEVATOR. We will recover LIGHT1, CAM2, and BSP1 by attaching them to the ELEVATOR recovery line and free-floating it to the surface.

Figure 10-1 shows a cartoon of how a recovery line will be pulled out from the elevator for LIGHT1, CAM2 and BSP1 to be attached to.



1. Line Basket in foam slot for deployme
2. ROV pulls out basket and lays horizontal
3. Pulls out line on bottom taut to end near BSP1
4. Brings BSP2 and connects loop, pulls taut
5. Brings CAM2 and connects loop, pulls taut
6. Bring LIGHT1 and connects loop, pulls taut
7. Attach weights/floats as necessary

Figure 9-1 Package recovery process.

During operations UH ACO shore personnel will be available to turn instrument power on and off to individual ports, control the overall system, and test components as we add them. This command and control will be done at UH. The AT&T Makaha Cable Station will be notified of our activity, in case there is some need (not expected at this point) for the shore personnel to operate from there. Good communications is essential. We will try controlling the ACO from a ship-based computer, to the extent of turning ports and off.

If all goes according to the plan laid out in detail in Appendix B and in the schedule in Table 10-1, the entire operation should be completed in the allotted time, with ~30 hours of contingency in Task 10.

The following table gives the major tasks and associated times.

Table 9-1 Cruise tasks and times (local HST time)

	Task	Start	HST hh:mm	End
1	Transit to Station ALOHA	06/07 06:30	9:30	06/07 16:00
2	ROV Dive 1 (LK-001), LIGHT4	06/07 16:00	2:50	06/07 18:50
3	Move LIGHT1	06/07 18:50	1:05	06/07 19:55
4	Move and connect LIGHT4	06/07 18:50	2:25	06/07 21:15
5	Move CAM2	06/07 21:15	1:10	06/07 22:25
6	Ascent and Recovery - end of Dive LK-001	06/07 22:25	6:40	06/08 05:05
7	ROV Dive LK-002, Deploy BSP3	06/08 05:05	4:10	06/08 09:15
8	Connect BSP3	06/08 09:15	3:55	06/08 13:10
9	Ascent and Recovery - end of Dive LK-002	06/08 13:10	6:40	06/08 19:50
10	ROV Dive 3 (LK-003), ELEVATOR	06/08 19:50	3:35	06/08 23:25
11	Rig ELEVATOR with BSP1, CAM2, LIGHT1	06/08 23:25	5:50	06/09 05:15
12	Recover ELEVATOR with BSP1, CAM2, LIGHT1	06/09 05:15	5:40	06/09 10:55
13	Final steps	06/09 10:55	9:00	06/09 19:55
13	Ascent and Recovery, end of Dive LK-003	06/09 19:55	2:50	06/09 22:45
14	ONR RAP work	06/09 22:45	96:00	06/13 22:45
15	Contingency	06/13 22:45	25:15	06/15 00:00
16	Transit to Honolulu	06/15 00:00	15:00	06/15 15:00
			201:35	

References

2011 cruise plan
http://aco-ssds.soest.hawaii.edu/ACO/docs/20110515_KM1116_Cruise_Plan_Howe_lo-res.pdf

2011 cruise report
http://aco-ssds.soest.hawaii.edu/ACO/docs/20110515_KM1116_Cruise_Plan_Howe_lo-res.pdf

2014 cruise plan
http://aco-ssds.soest.hawaii.edu/ACO/docs/ACO_3_Cruise_Plan_2014.pdf

2014 cruise report
http://aco-ssds.soest.hawaii.edu/ACO/docs/ACO_3_Cruise_Report_2014.pdf

Oceans 11 paper
Howe, B. M., R. Lukas, F. Duennebier, and D. Karl, ALOHA cabled observatory installation, *OCEANS 2011*, 19-22 Sept. 2011, URL:
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6107301&isnumber=6106891
or
http://aco-ssds.soest.hawaii.edu/Howe_et_al_ACO_Oceans11.pdf

Additional photographs and other system documentation can be found on the project web site http://aco-ssds.soest.hawaii.edu/index.html. Also see the ROV *Jason* Virtual Control Van videos from the KM-11-16 June 2011 cruise and the KM-14-26 November 2014 cruise, http://4dgeo.whoi.edu/jason/.

Appendix A – ACO Diagrams

The following diagrams show the OBS port assignments, current and planned.

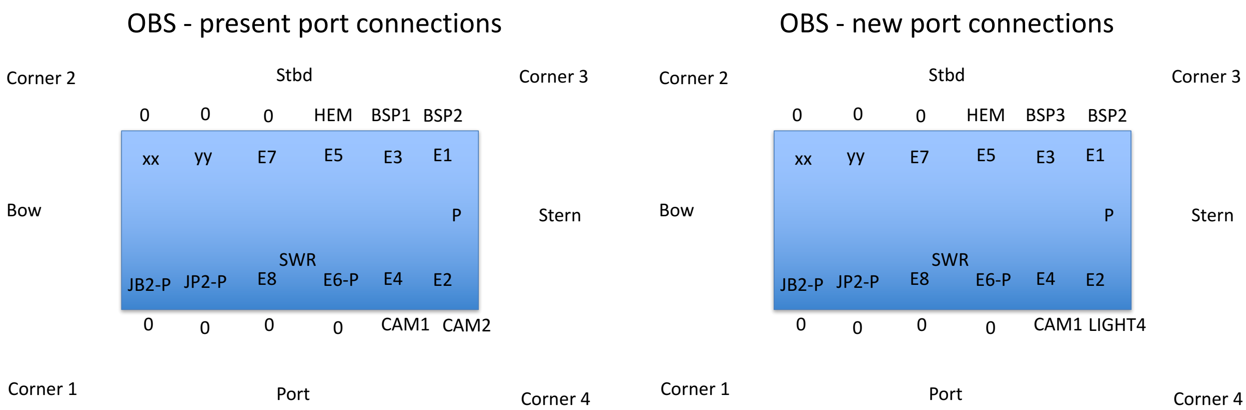


Figure A-1 ACO Observatory port connections – present and new (P = parking)

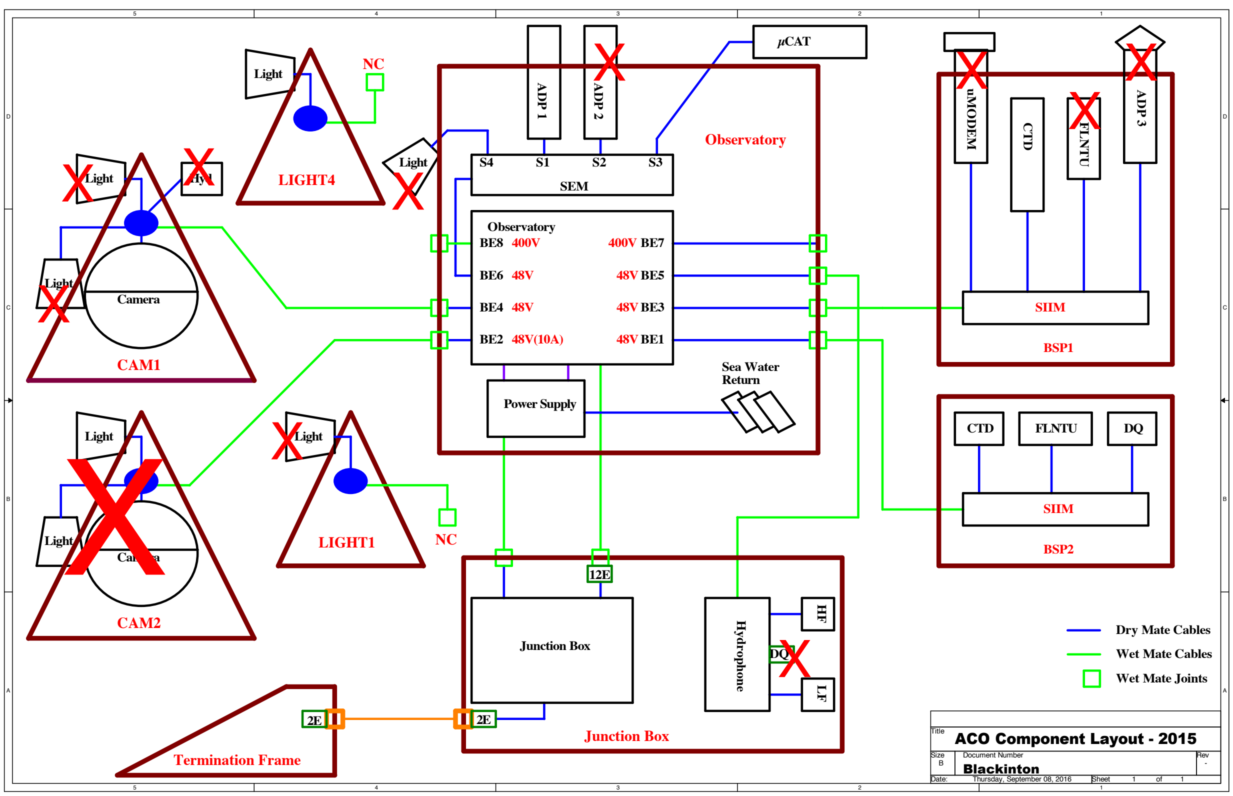


Figure A-2 ACO connections – September 2015; x = failed

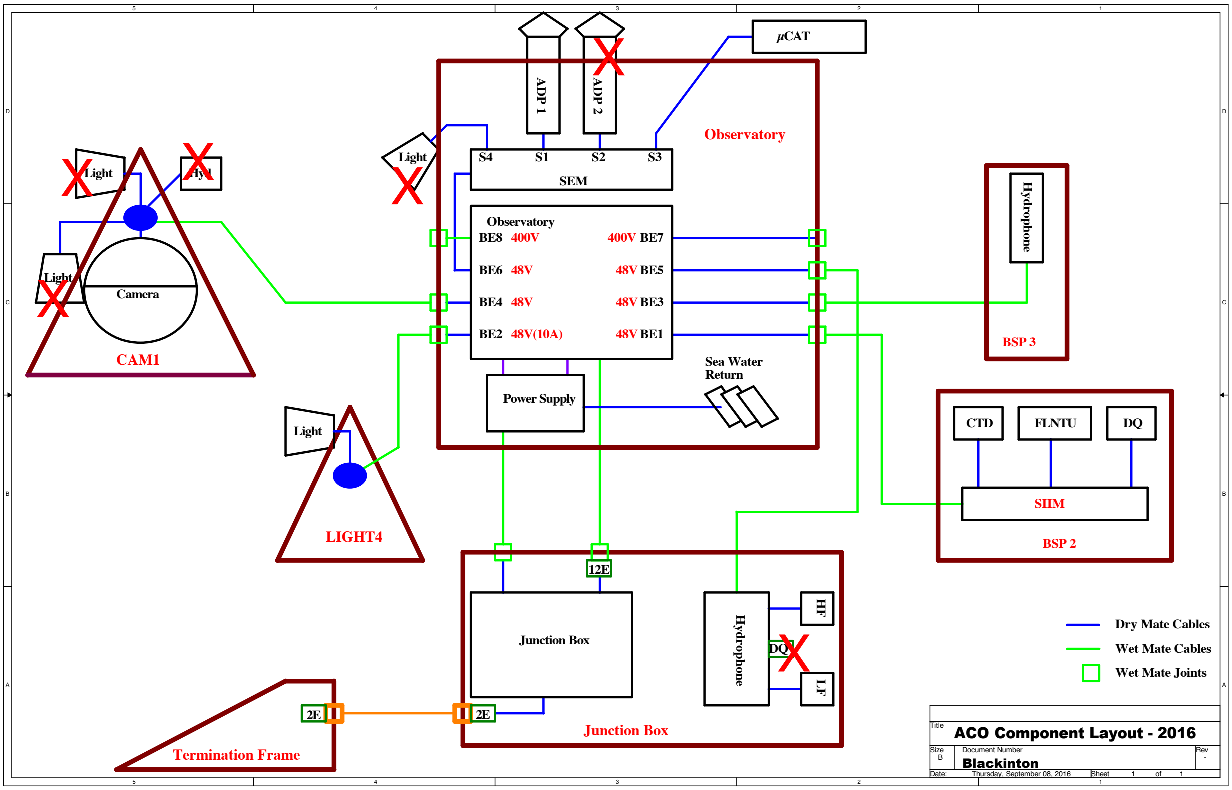


Figure A-3 Planned ACO connections – June 2017; x = failed

Appendix B – ACO Operations

The following table gives the detailed ACO tasks associated with deploying and recovering the instrumentation.

Table B-1 ACO tasks for deployment

			Local HST	
		06/07 06:30		**06/15 15:00**
	Task	**Start**	**hh:mm**	**End**
1	**Transit to Station ALOHA**			
1	Transit from Ko Olina to Station ALOHA	06/07 06:30	9:00	06/07 15:30
2	Load ROV basket: knive,s chisels for cleaning sea water return (SWR), 1 Environmental Cover (EC), pin-protecting dummy with T-handle, , snap-hook-lines and bungies for securing hoses, SonarBell	06/07 15:30	0:00	06/07 15:30
3	Establish DP position (A-frame of ship) ~50 m S of the Cable Termination (CT)	06/07 15:30	0:30	06/07 16:00
2	**ROV Dive 1 (LK-001), LIGHT4**			
1	Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. Descend 40 m/in	06/07 16:00	0:20	06/07 16:20
2	Test ROV periodically all the way to bottom. Stop 15 m above bottom and undock	06/07 16:20	1:40	06/07 18:00
3	Get bearings and locate cable, OBS and other items; interact with shore using CAM1 to watch ROV	06/07 18:00	0:20	06/07 18:20
4	Look around area, establish nav references	06/07 18:20	0:20	06/07 18:40
5	Move ship and ROV over LIGHT1	06/07 18:40	0:10	06/07 18:50
3	**Move LIGHT1**			
1	Move to LIGHT1 connector on bottom, E side of OBS (between corners 2 and 3)	06/07 18:50	0:15	06/07 19:05
2	Pick up connector/yale grip	06/07 19:05	0:10	06/07 19:15
3	Move to LIGHT1 and place connector in holster and secure with bungie	06/07 19:15	0:20	06/07 19:35
4	LIGHT1 lifting loop on horn, dock ROV, lift, and move ROV and ship to 15 m SE of BSP1; set down LIGHT1	06/07 19:35	0:20	06/07 19:55
4	**Move and connect LIGHT4**			
1	Move ship and ROV (still docked) to LIGHT4; undock	06/07 18:50	0:15	06/07 19:05

	2	Set LIGHT4 frame upright	06/07 19:05	0:10	06/07 19:15
	3	Remove tracking beacon 3 and put in basket	06/07 19:15	0:10	06/07 19:25
	4	Release bottom weight from LIGHT4	06/07 19:25	0:10	06/07 19:35
	5	LIGHT4 lifting loop on horn, dock ROV, move ship and ROV to previous LIGHT1 position. Set down and undock. Orient with light pointed toward OBS. Hose will be facing W	06/07 19:35	0:25	06/07 20:00
	6	Pull pins to release hose figure-8	06/07 20:00	0:10	06/07 20:10
	7	Lift out ODI connector from holster. This releases pin protecting dummy. Set down connector, pick up dummy and put in basket. Grasp yale grip, and fly hose to OBS by port E2 and set down ROV	06/07 20:10	0:15	06/07 20:25
	8	Confirm port E2 power is off	06/07 20:25	0:10	06/07 20:35
	9	Unplug CAM2 from Port E2, set down on OBS	06/07 20:35	0:10	06/07 20:45
	10	Connect LIGHT4 to port E2	06/07 20:45	0:10	06/07 20:55
	11	Inform shore of connection, to turn on LIGHT4 on port E2	06/07 20:55	0:10	06/07 21:05
	12	Test LIGHT4	06/07 21:05	0:10	06/07 21:15
5	**Move CAM2**				
	1	Plug CAM2 connector into pin-protecting dummy with (small) T-handle, from basket	06/07 21:15	0:15	06/07 21:30
	2	Take CAM2 connector to CAM2, place in holster and secure with bungie, clear cable	06/07 21:30	0:10	06/07 21:40
	3	CAM2 Lift loop on horn, dock ROV, move CAM2 10 m SE of BSP1, set down and undock	06/07 21:40	0:20	06/07 22:00
	4	Deploy SonarBell next to Cable Termination CT	06/07 22:00	0:10	06/07 22:10
	5	Clear area at stern of OBS. Move poster to NW corner of OBS	06/07 22:10	0:15	06/07 22:25
6	**Ascent and Recovery - end of Dive LK-001**				
	1	Dock ROV	06/07 22:25	0:10	06/07 22:35
	2	ROV ascends	06/07 22:35	2:00	06/08 00:35
	3	Recover ROV	06/08 00:35	0:30	06/08 01:05
	4	ROV deck checks, install new, charged battaries in beacon 3 (from LIGHT4)	06/08 01:05	4:00	06/08 05:05
7	**ROV Dive LK-002, Deploy BSP3**				
	1	Position ship to BSP3 drop point 100 m N of CT. Deploy ROV, holds initially at 30 m	06/08 05:05	0:30	06/08 05:35
	2	Deploy BSP3 free fall, BSP3 with USBL Beacon 3, pin-protecting dummy on connector with pull-rope	06/08 05:35	0:30	06/08 06:05

	3	Move ship and ROV as BSP3 falls	06/08 06:05	1:00	06/08 07:05
	4	As appropriate move ship and ROV to intercept BSP3 (conservatively!)	06/08 07:05	0:40	06/08 07:45
	5	After BSP3 lands, undock and go to it (move ship as necessary)	06/08 07:45	0:30	06/08 08:15
	6	Cut bottom weight from BSP3	06/08 08:15	0:10	06/08 08:25
	7	BSP3 lift loop on horn, dock ROV, and move ROV and Ship to location 45 m N of CT, set down, hose reel facing OBS, undock	06/08 08:25	0:30	06/08 08:55
	8	Attach the BSP3 hose reel to the front of the ROV basket, dock	06/08 08:55	0:20	06/08 09:15
8	**Connect BSP3**				
	1	Move ROV and ship SSW, between CT and JBOX, over cables, just to SE of OBS	06/08 09:15	0:30	06/08 09:45
	2	Fly SW until all hose off reel and connector free (connector falls to bottom), undock, leave reel on bottom for later retrieval	06/08 09:45	0:05	06/08 09:50
	3	Take connector to port E3 on SE side OBS, set down ROV	06/08 09:50	0:10	06/08 10:00
	4	Set down BSP3 connector on mid-deck of OBS under E3	06/08 10:00	0:05	06/08 10:05
	5	Confirm from shore that BSP1 port E3 is off	06/08 10:05	0:10	06/08 10:15
	6	Remove BSP1 connector from Port E3	06/08 10:15	0:10	06/08 10:25
	7	Remove pin protecting dummy (with rope pull) from BSP3 connector	06/08 10:25	0:10	06/08 10:35
	8	Plug BSP3 connector into port E3	06/08 10:35	0:15	06/08 10:50
	9	Have shore turn on BSP3 and test	06/08 10:50	0:20	06/08 11:10
	10	Plug BSP1 connector into pin-protecting dummy with (small) T-handle from basket	06/08 11:10	0:10	06/08 11:20
	11	Go to BSP3, ship following, lifting loop on horn, dock, and move it next to JBOX as close as possible on the E side (fly up lifting the cable)	06/08 11:20	0:30	06/08 11:50
	12	Undock, Remove USBL Beacon 3 from BSP3 and put in basket; adjust BSP3 position	06/08 11:50	0:20	06/08 12:10
	13	Reposition LIGHT4 and Poster	06/08 12:10	0:30	06/08 12:40
	14	Clean up	06/08 12:40	0:30	06/08 13:10
9	**Ascent and Recovery - end of Dive LK-002**				
	1	Dock ROV	06/08 13:10	0:10	06/08 13:20
	2	ROV ascends	06/08 13:20	2:00	06/08 15:20
	3	Recover ROV	06/08 15:20	0:30	06/08 15:50

	4	ROV deck checks, charge beacon 3 (from LIGHT4)	06/08 15:50	4:00	06/08 19:50
10		**ROV Dive 3 (LK-003), ELEVATOR**			
	1	Position ship 100 m E of BSP1	06/08 19:50	0:20	06/08 20:10
	2	Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. Pin protecting dummy with T-handle, snap-hook lines for elevator	06/08 20:10	0:20	06/08 20:30
	3	Test ROV at 100 m	06/08 20:30	0:10	06/08 20:40
	4	Deploy ELEVATOR free fall, with USBL Beacon 3, with bait for camera attached	06/08 20:40	0:20	06/08 21:00
	5	ROV continues down, follows ELEVATOR	06/08 21:00	1:45	06/08 22:45
	6	On bottom, undock, orient, locate and move to ELEVATOR; cut off descent weight	06/08 22:45	0:20	06/08 23:05
	7	Move ship to ELEVATOR, lift loop on horn, dock	06/08 23:05	0:20	06/08 23:25
11		**Rig ELEVATOR with BSP1, CAM2, LIGHT1**			
	1	Move ELEVATOR to ~58 m E of BSP1, orient line basket to W, manual release to E; undock	06/08 23:25	0:30	06/08 23:55
	2	Measure range and bearing to BSP1	06/08 23:55	0:05	06/09 00:00
	3	Remove bait from ELEVATOR	06/09 00:00	0:10	06/09 00:10
	4	Set bait in front of CAM1 (ship follow)	06/09 00:10	0:20	06/09 00:30
	5	Go to OBS and disconnect BSP1 from OBS dummy; connect pin-protecting dummy with T-handle	06/09 00:30	0:15	06/09 00:45
	6	Go to BSP1 with connector and hose	06/09 00:45	0:10	06/09 00:55
	7	Secure BSP1 connector in holster, dress hose	06/09 00:55	0:10	06/09 01:05
	8	On BSP1, lower and latch CTD mast; lower and latch WHOI micromodem mast	06/09 01:05	0:30	06/09 01:35
	9	Measure range and bearing to ELEVATOR	06/09 01:35	0:05	06/09 01:40
	10	Go to ELEVATOR (ship follows)	06/09 01:40	0:10	06/09 01:50
	11	Lift loop on horn, dock, move ELEVATOR to refined position, set down in optimal orientation and undock	06/09 01:50	0:10	06/09 02:00
	12	Remove line basket from ELEVATOR and set on bottom	06/09 02:00	0:10	06/09 02:10
	13	Pull out recovery line to BSP1, ship following	06/09 02:10	0:20	06/09 02:30
	14	Connect Snap-hook-line between end of recovery line and BSP1	06/09 02:30	0:10	06/09 02:40
	15	Go to ELEVATOR (ship following), ELEVATOR lift loop on horn, dock, move E, set down when line just taut	06/09 02:40	0:20	06/09 03:00

	16	Move to CAM2, ship following	06/09 03:00	0:10	06/09 03:10
	17	CAM2 lift loop on horn, dock, move CAM2 to recovery line, set down, undock, connect Snap-hook-line to CAM2 loop	06/09 03:10	0:15	06/09 03:25
	18	Connect other end of Snap-hook-line to recovery line loop	06/09 03:25	0:15	06/09 03:40
	19	Move to LIGHT1	06/09 03:40	0:10	06/09 03:50
	20	LIGHT1 lift loop on horn, dock, move LIGHT1 to recovery line, set down, undock, connect Snap-hook-line to LIGHT1 loop	06/09 03:50	0:15	06/09 04:05
	21	Connect other end of Snap-hook-line to recovery line loop	06/09 04:05	0:10	06/09 04:15
	22	Dress connecting lines, move packages to tauten lines	06/09 04:15	0:40	06/09 04:55
	23	Inspect ELEVATOR and packages	06/09 04:55	0:20	06/09 05:15
12	**Recover ELEVATOR with BSP1, CAM2, LIGHT1**				
	1	Position ship 40 m E of ELEVATOR; ROV observing just E of ELEVATOR (ready to manually activate release if necessary, and to observe).	06/09 05:15	0:20	06/09 05:35
	2	Acoustically release ELEVATOR with packages daisy chained	06/09 05:35	0:20	06/09 05:55
	3	ELEVATOR and packages ascend	06/09 05:55	1:30	06/09 07:25
	4	ROV docks and ascends, ship follows elevator, ROV stops ascent when ELEVATOR connected to ship, or at 50 m	06/09 07:25	1:30	06/09 08:55
	5	Ship deploys small boat to attach line to ELEVATOR, brings to ship	06/09 08:55	1:00	06/09 09:55
	6	Recover ELEVATOR and packages with crane, small capstan/winch	06/09 09:55	1:00	06/09 10:55
13	**Final steps**				
	1	ROV returns to bottom (can happened while recovering ELEVATOR on ship)	06/09 10:55	1:00	06/09 11:55
	2	Adjust LIGHT4 and CAM1 as necessary based on directions from shore	06/09 11:55	0:30	06/09 12:25
	3	Move BSP3 to final position NW of OBS (near TAAM); maximize distance given hose	06/09 12:25	0:30	06/09 12:55
	4	Re-adjust ACO sign	06/09 12:55	0:30	06/09 13:25
	5	Inspect BSP2 for shifting	06/09 13:25	0:30	06/09 13:55
	6	Dress all cables	06/09 13:55	1:00	06/09 14:55
	7	Clean SWR on W side of OBS	06/09 14:55	1:00	06/09 15:55

			Start	Duration	End
	8	Fly over each package to inspect and get good navigation fixes and photos	06/09 15:55	1:00	06/09 16:55
	9	Conduct a mow-the-lawn mosaic	06/09 16:55	1:00	06/09 17:55
	10	Photo op - coordinate ROV Luukai and CAM1 control on shore	06/09 17:55	1:00	06/09 18:55
	11	Recover two reels: BSP3 reel first on basket, BSP2 reel held with Mantis; test ROV auto-track	06/09 18:55	1:00	06/09 19:55
13	**Ascent and Recovery, end of Dive LK-003**				
	1	ROV ascends	06/09 19:55	2:00	06/09 21:55
	2	Recover ROV	06/09 21:55	0:30	06/09 22:25
	3	Final deck checks	06/09 22:25	0:20	06/09 22:45
14	**ONR RAP work**				
	1	ONR RAP work	06/09 22:45	96:00	06/13 22:45
15	**Contingency**				
	1	Contingency	06/13 22:45	25:15	06/15 00:00
16	**Transit to Honolulu**				
	1	Transit	06/15 00:00	12:00	06/15 12:00
	2	Holding off Honolulu for entry	06/15 12:00	2:00	06/15 14:00
	3	Arrive	06/15 14:00	1:00	06/15 15:00
			06/07 06:30	**201.6** **8.40**	**06/15 15:00**

	Start	Duration	End
Dive 1	06/07 16:00	9:05	06/08 01:05
Dive 2	06/08 05:05	10:15	06/08 15:20
Dive 3	06/08 20:10	26:15	06/09 22:25
		45:35	

Appendix C – ONR RAP Work

On the *R/V Kilo Moana* there is a 4x4 transducer array located in a coffer dam on the hull of the ship (Figure C-1). The transducers were produced by Massa (TR-1075A) and are rated with a 100 Ω impedance at 4kHz. For this experiment only one transducer will be used. The purpose for sending these shipboard acoustic transmissions through the water column is to perform reliable acoustic path (RAP) tomography.

Acoustic signals can take several different pathways from the transmitter to the receiver. In the case of this experiment, an acoustic transmission can be received in a direct path, a bottom-surface bounce, a bottom-surface-bottom-surface bounce, and so on. The reliable acoustic path is the direct path taken, ensuring a minimum loss of energy from attenuation and scattering. Attenuation is the absorption of the acoustic signal as it travels further from the source and the scattering is attributed to the bottom/surface bounces. This results in the strongest reception of all possible paths and will be the most accurate/precise for timing purposes. Since the sound speed field of the ocean is fairly uniform and constant, sending an acoustic transmission from the surface down to the seafloor guarantees a direct path arrival given a particular launch angle and range (Figure C-2).

Ocean acoustic tomography is the spatial mapping of the ocean's sound speed. This is done by recording an acoustic ray's path and its subsequent travel time. A simple calculation is made to find the average sound speed for each ray path (distance traveled divided by time). By increasing the number of intersecting pathways the spatially dependent sound speed field can be resolved using linear inverse theory. Using this technique allows for an indirect measurement of the oceans temperature and to a lesser extent subsurface currents.

The overall goal of this project is to use acoustic transmissions up to a 30 km radius (60 km diameter) to map the oceans sound speed of this "teacup" volume (Figure C-2). The setup of these tests can be considered an extension of the inverted echosounder combined with the precise positioning and timing of seafloor geodesy. Fluctuations in travel time correspond to temperature changes in the acoustic path.

For the upcoming cruise, measurements will be recorded through an audio interface (Focusrite Scarlett 6i6) connected to an onboard laptop through USB. The Scarlett will also be relaying the computer generated acoustic transmission to the power amplifier (Proel HPX2800). The power amplifier will be directly connected with one of the transducers in Figure C-1. Along this cable, an interface module will be connected to allow measurement of the voltage and current by the Scarlett. Once the signal is sent, a reference transducer (located beside the transmitting transducer) will pick up the transmission. This will be input to the Scarlett to ensure the waveform matches the one produced by the laptop and to increase timing accuracy. The Scarlett will also have an input designated for the PPS that is generated by ship's navigation POS-MV system onboard (Figure C-3). All of the inputs into the Scarlett will also be available for real-time viewing with an oscilloscope.

The primary signals to be tested will be a LFM sweep and M-sequence both with a center frequency of 4134.375 Hz, 1378.125 Hz bandwidth, and 22.5 ms duration. This cycle will be repeated every 30 s to allow enough time between each transmission for no overlapping of the direct, BS, BSBS, or BSBSBS ray path arrivals. The signal duration was selected to have the waveform remain insensitive to Doppler shift, but also provide a long enough pulse to provide sufficient processing gain (PG), we expect.

These acoustic signals will be transmitted on the approach and departure from ACO. After arriving at ACO, transmissions should be able to continue during this time as the frequency range used by the ROV is around 15 kHz and will not overlap with the signals being sent. This will provide a chance to measure the time travel changes from the transducer to the hydrophone over a tidal cycle(s). The average sound speed for the water column at ACO is just above 1500 m/s and the tidal range during this cruise will be about 0.5 m. Given this, the travel time difference between high and low tide should be about 0.333 ms.

During the cruise, we will make acoustic transmissions while having the *R/V Kilo Moana* traverse various pathways around/near ACO. An ideal scenario would have the *R/V Kilo Moana* run a circular track around the hydrophone at a radius near our desired maximum range (~30 km). Since the *R/V Kilo Moana* is capable of sailing at 12 kts this would require about 8.5 hours of time. Decreasing the radius and/or only sailing for half the circle would significantly reduce the required allotted time and provide more time for other testing (Figure C-4).

Additional LFM and M-seq signals lasting 2 minutes will be transmitted to determine coherent averaging times. Per ONR guidance regarding marine mammal considerations, with an associated permit, these will be transmitted only during daylight hours, with 3 hour separation. Fifteen minutes before and during each transmission, one watchstander/lookout on the bridge will keep a look out for marine mammals; if there are any present within 200 m, transmissions will not start, or will stop.

Figure C-1 Housing and interior view of the 4x4 transducer array located on the hull of the R/V Kilo Moana

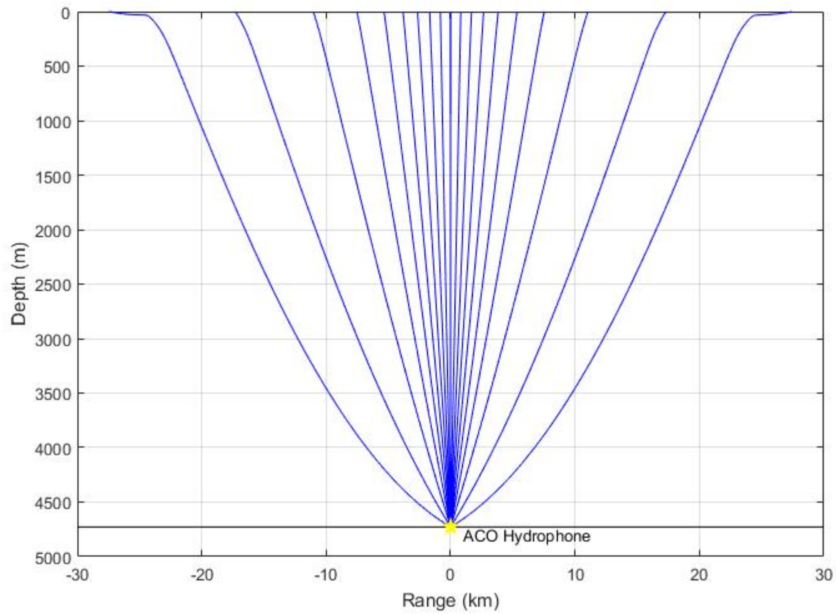


Figure C-2 Reliable acoustic paths for ranges extending outwards of ~30 km. Each pathway corresponds to a different initial launch angle and was calculated using August 2015 HOTS CTD data. Note: X and Y axis are not scaled equally.

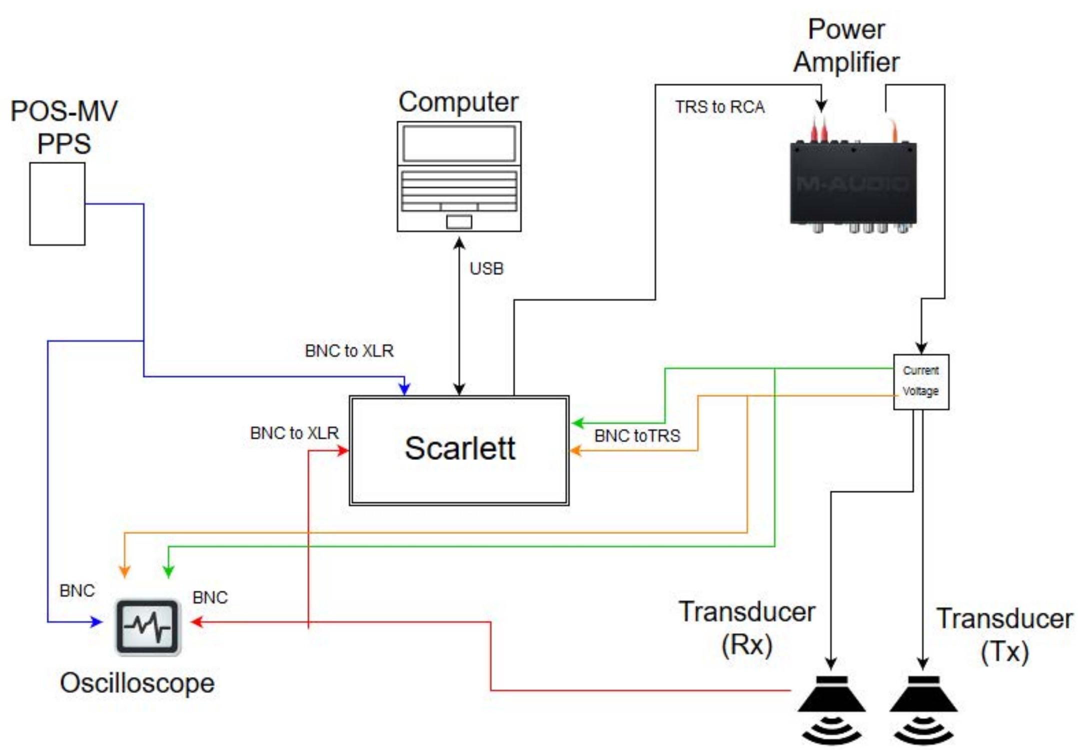


Figure C-3 Diagram of the experiment setup.

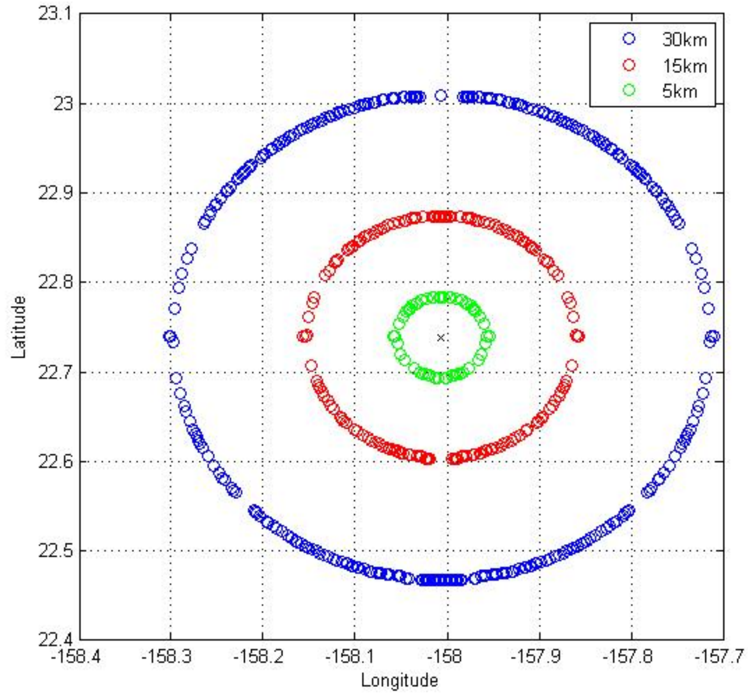


Figure C-4 A few possible circular paths that can be taken around the ACO hydrophone

Appendix D – Cruise Participants and Contacts List

Kilo Moana: In Port Ship Numbers: (808) 842-9817 | (808) 842-9834
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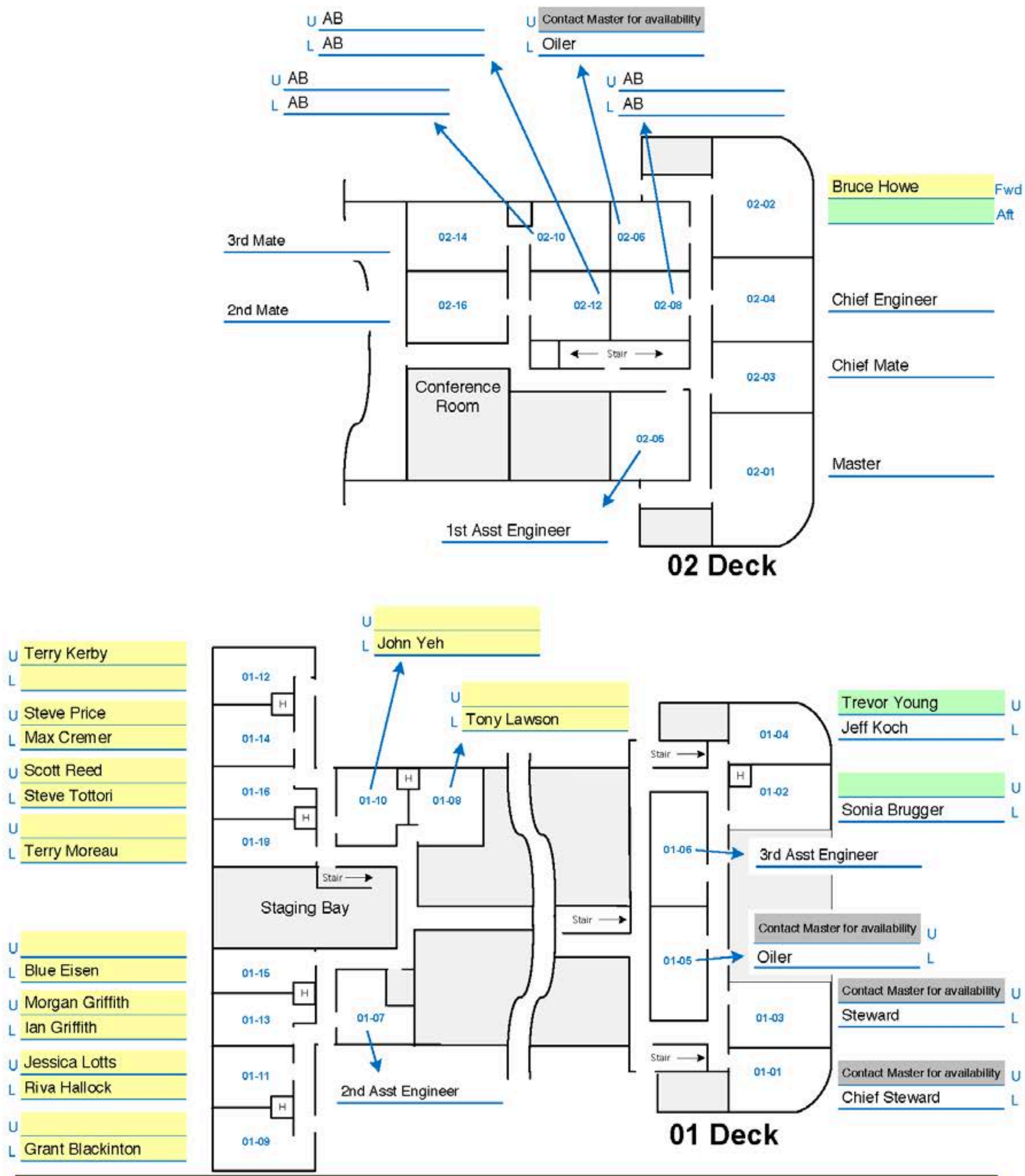
Appendix D – Berthing Plan

R/V Kilo Moana Berthing Plan - Cruise: KM-17-06



All 21 science berths in yellow must be filled first. The next three are in green. There are two additional bunks available through the Master. No members of the opposite sex, excepting a married couple, may be berthed together. (UHMC SQ COQP-1.0-25)

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Appendix E – Acronyms and abbreviations

12E	Electrical connector with 12 electrical circuits
2E	ODI NRH Connector with 2 electrical circuits and 4 optical circuits
4E	Electrical connector with 4 electrical circuits
ACO	ALOHA Cabled Observatory
ACP	Acoustic current profiler
ADCP	Acoustic Doppler current profiler
AMM	Aloha Mars Mooring Secondary Node
BSP	Basic Sensor Package
CAM	Camera Tripod
$CTDO_2$	Conductivity, temperature, depth, oxygen sensor package
DMAS	Data Management and Archiving System
DP	Dynamic positioning
EC	Environmental Cover – protective cap for unconnected ODI bulkheads
EM	Electrical-Mechanical
EO	Electrical-Optical
EOM	Electrical-Optical-Mechanical
HEM	Hydrophone Experiment module, resides on JBOX
HOT	Hawaii Ocean Timeseries
μSEM	micro Science Experiment Module
JBOX	Frame with junction box and HEM with cables and connectors
MARS	Monterey Accelerated Research System
MBARI	Monterey Bay Aquarium Research Institute
NRH	Nautilus Rolling Hybrid – optical and electrical ODI connector
NTP	Network Time Protocol
OBS	Observatory package
ODI	Ocean Design, Inc. wet mateable connector
PBOF	Pressure balanced, oil filled
PMACS	Power Management and Control System
PPS	Pulse Per Second (GPS-derived precise timing signal)
PTP	Precise Time Protocol
PTT	Port Test Tool
ROV	Remotely Operated Vehicle
SIIM	Science Instrument Interface Module
SMF	Single mode fiber
TF	Termination Frame