Cruise Plan for R/V *Kilo Moana* KM-19-13: ALOHA Cabled Observatory Service and ONR Kauai Cable 9 – 16 July 2019

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Version 2.0

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1. Introduction

The purposes of these NSF and ONR-funded cruises on the R/V *Kilo Moana* are, respectively, to:

- service infrastructure and instrumentation on the ALOHA Cabled Observatory (ACO), and
- diagnose a cable fault on a seafloor instrumentation cable on the north side of Kauai.

ACO is the deepest operating cabled observatory on the planet. On this cruise specifically, a new basic sensor package (BSP4) will be deployed, BSP2 will be recovered, repaired, and redeployed, a camera and light (CAM2, LIGHT1) will be recovered, BSP3 hydrophone will be recovered (recently failed, may not be reflected in certain figures), and various housekeeping tasks done. The University of Hawaii remotely operated vehicle ROV *Lu'ukai* is essential to performing the required tasks.

The second part of the cruise is to use the ROV to recover an instrumentation cable from 100 m water depth, cut and test the cable and instrument, splice it and redeploy, and survey some distance on each side of the splice, and possibly inspect the instrumentation on the seaward end.

RAP (reliable acoustic path) acoustic transmissions will be during time at Station ALOHA, in consultation with ONR.

The cruise is 8 days long, from 0000 Tuesday 9 July – 1800 Tuesday 16 July 2019. After a shallow test dive off Honolulu, the ship will proceed 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 one ROV dive, with 4 elevator operations vertically transporting instrument packages. Then we proceed to the northwest coast of Kauai to perform the cable work. Table 1-1 gives coordinates of relevant points See Figure 1-1 for a map with nominal cruise lines.

	Depth m	Latitude deg	N minutes	Longitude deg	W minutes
UHMC, Pier 35		21°	18.933	157°	52.628
Honolulu Buoy		21	16	157	54
Test dive site	430	21	14.915	157	58.558
Barbers Point WP		21	16	158	09
Ka'ena Ridge WP		21	33	158	20
ACO Cable Termination Frame (TF)	4728	22	44.324	158	00.372
Station ALOHA		22	45	158	00
Kauai cable North cut point	75	22	12.853	159	38.484
Kauai cable seaward end/acoustic source	811	22	20.9493	159	34.19544

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. This is then followed by a brief description of the Kauai cable and required work; more detail is in an accompanying document. The ROV system is described, including the navigation system. The ship and deck configuration are described followed by a section on responsibilities. 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, and acronyms.

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

2. ACO Description

Information on the previous service cruises (KM-18-09, KM-17-07, 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 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.

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. A subsequent service cruise in November 2014 removed a failed secondary node and added CAM2, LIGHT1, and basic sensor package BSP1. All of these subsequently failed, with connectors known or suspected. 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. The KM-17-07 cruise was a failure from the ACO service point of view, as the main ship's winch failed at the start and in the process of recovering the cable, the fibers were broken at 4500 m. During the KM-18-09 cruise, BSP3 with hydrophone and secondary node 1 SN1 were deployed. BSP2 was damaged during repair. BSP1 was recovered.

Photographs of the system at various stages are shown below to familiarize the cruise participants and a brief description of various components is 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.

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). CAM1 is working with LIGHT4, so we will be leaving it in place (though we may move it a little). LIGHT4 has been moved off to the east for recovery. CAM2 must be recovered. BSP2 (with ODI connector on frame) needs to be recovered, repaired and redeployed.

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.

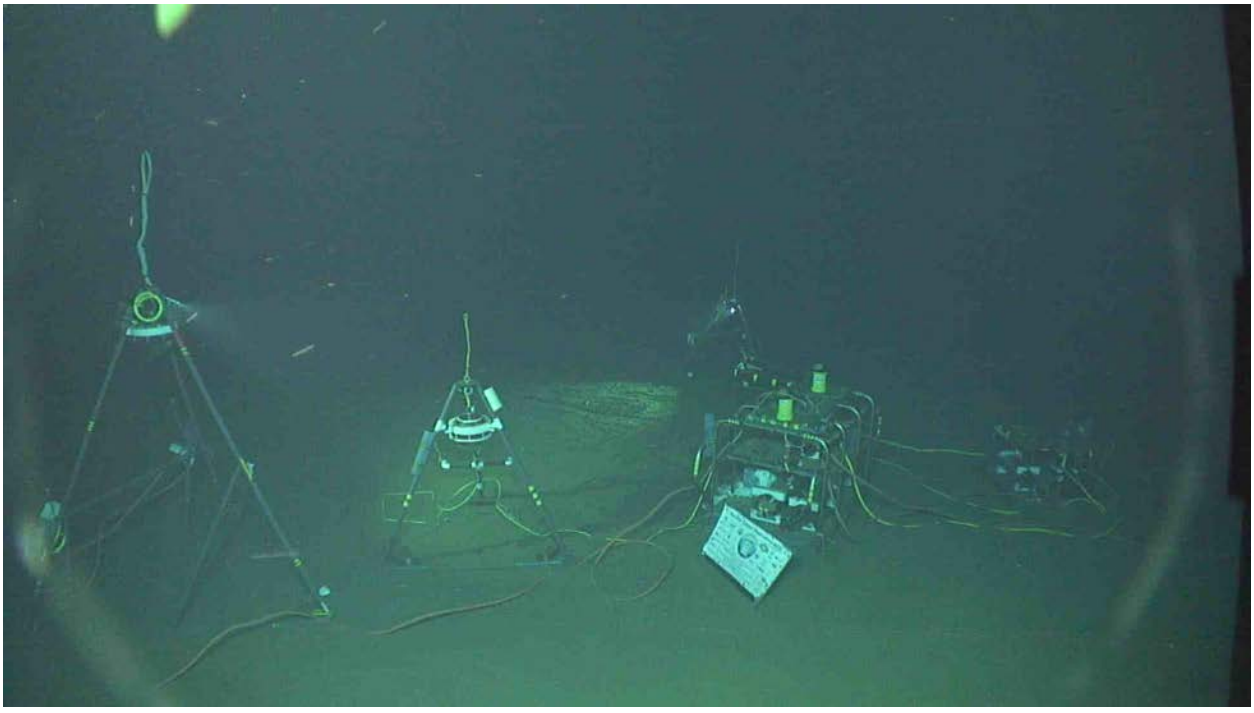

Figure 2-1 Image of system at the end of the November 2014 cruise.

Figure 2-2 The cable termination frame on 6 June 2011

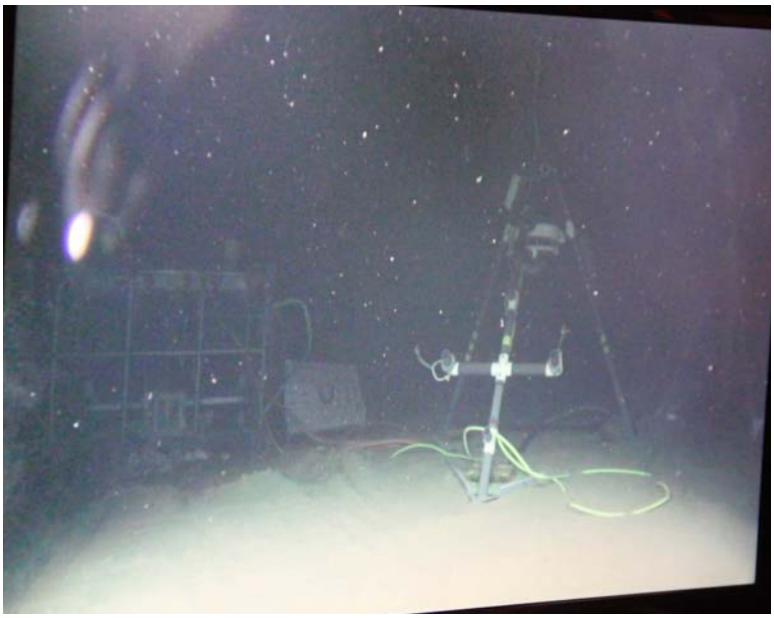

Figure 2-3 From Lu'ukai, the observatory, banner acknowledging organizations who have contributed to ACO, and CAM1

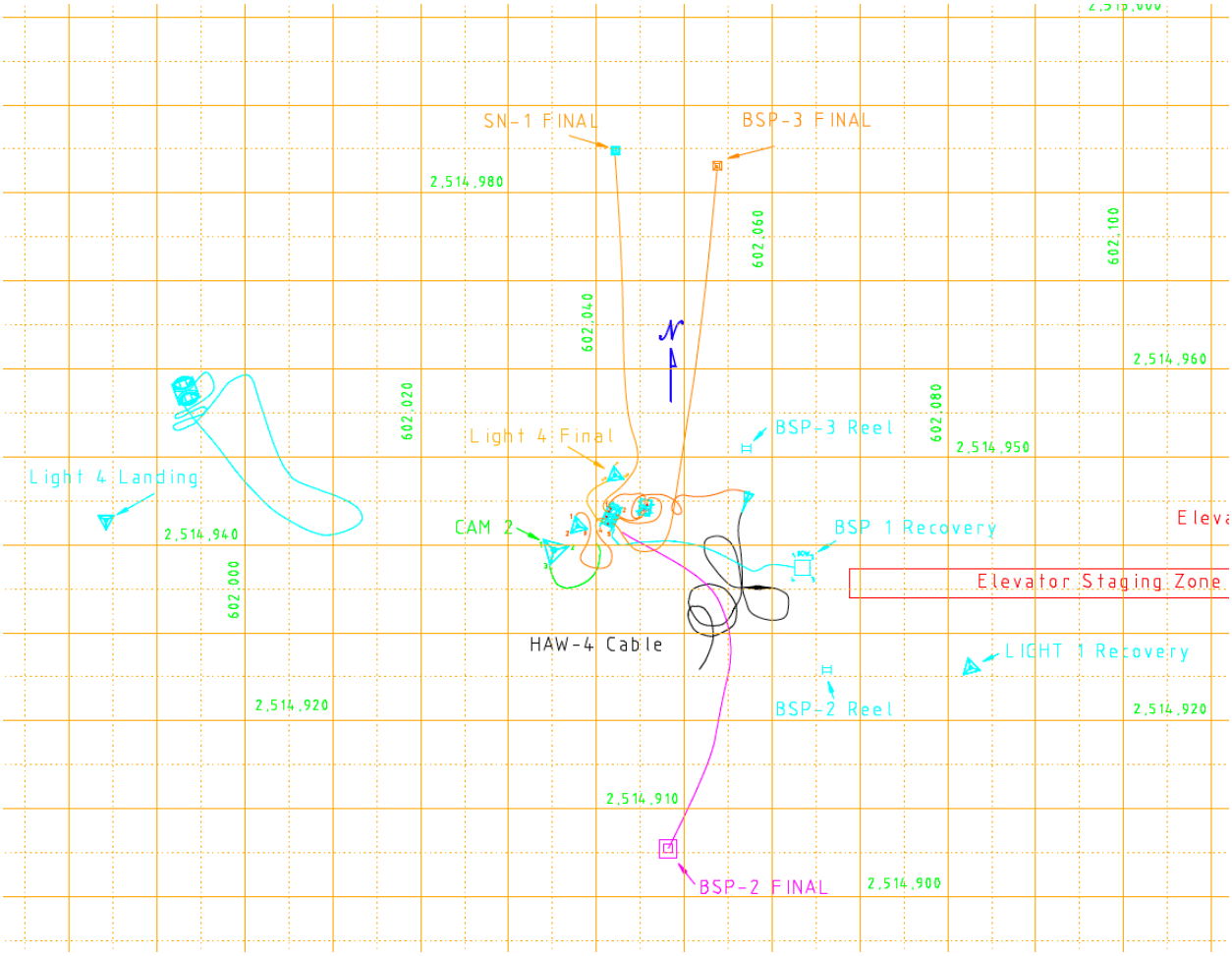

Figure 2-4 Present ACO seafloor configuration. Fred's plaque is 215 m NW of Cable Termination

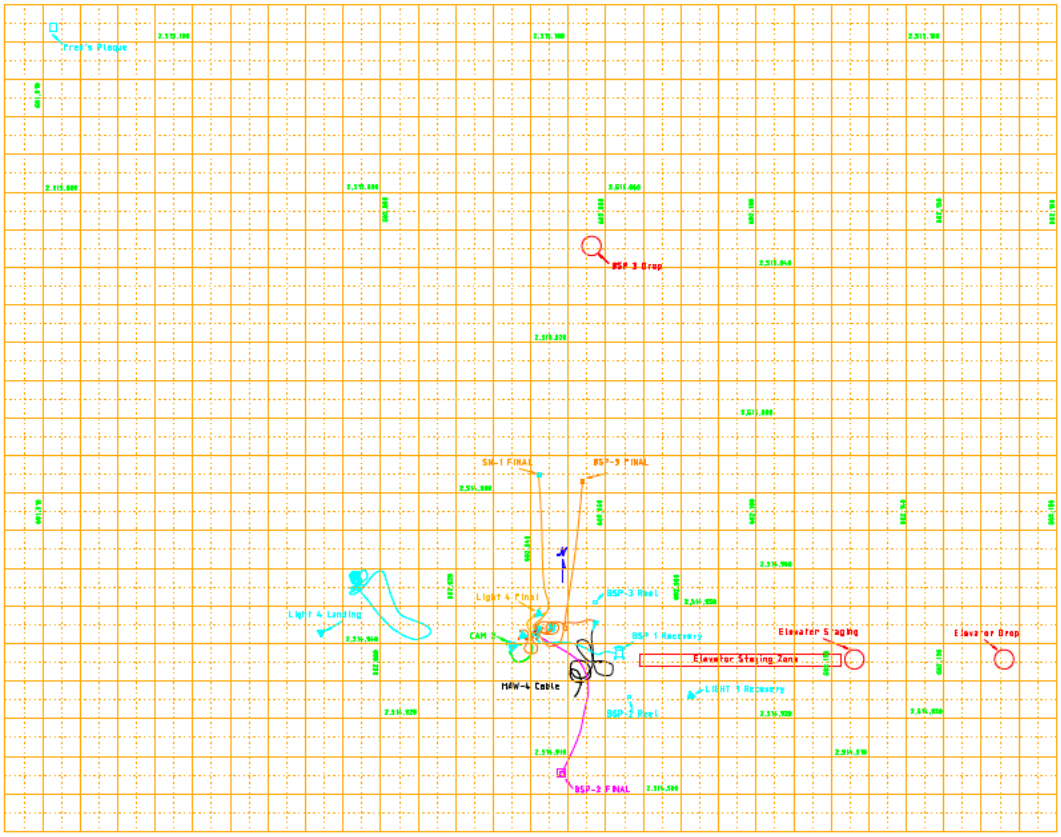

Figure 2-5 Full map of area, after June 2018 cruise.

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.

The observatory (OBS) is connected to the JBOX. 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 2-6 OBS frame (on deck and seafloor).

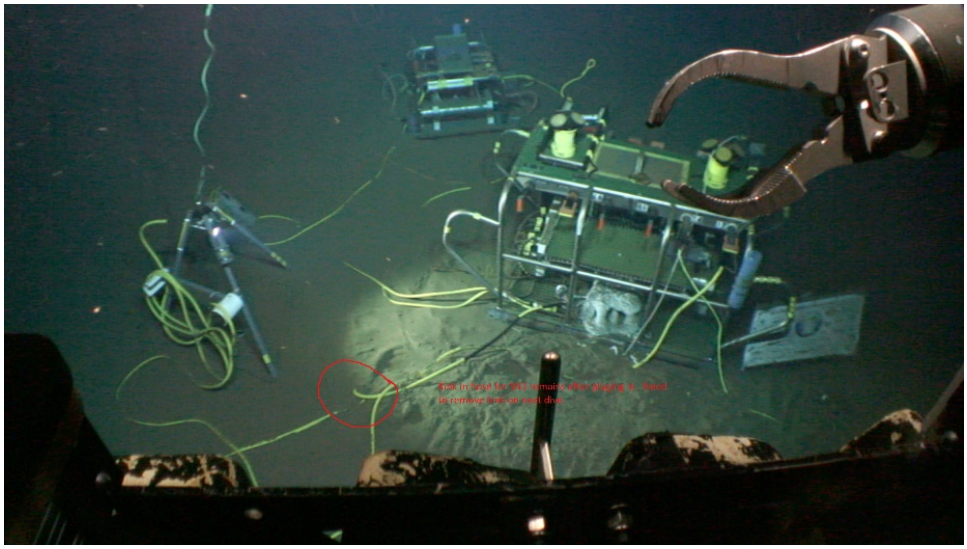

Figure 2-7 View at end of June 2018.

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. 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 fiberglass uni-strut and grating. Stainless steel brackets and fasteners are used where necessary.

Figure 2-8 CAM2+LIGHT1, and LIGHT1 – stand alone (with holsters)

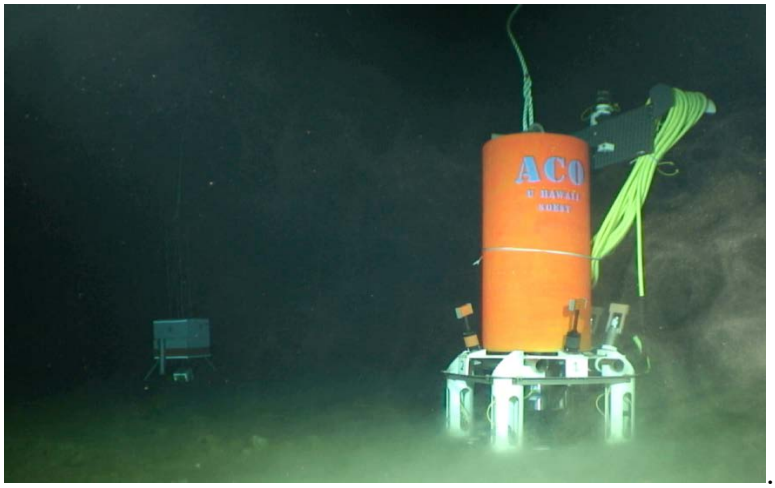

Figure 2-9 SN1 and BSP3 in background.

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. 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.

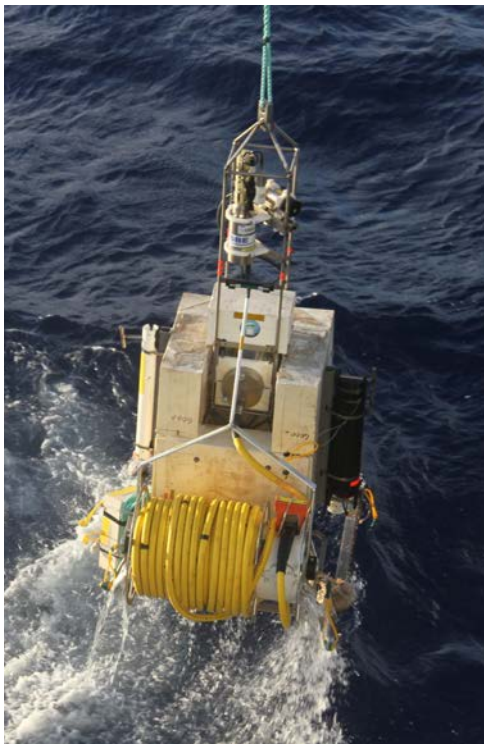

Figure 2-10 BSP2 with cable reel holding 50 m of hose.

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, one ROV dives and 3 ELEV trips are required.

BSP4 will be the single new instrument package deployed. On BSP4, the SIIM brings together the following sensors: Seabird conductivity, temperature, depth (pressure) and oxygen pumped (CTDO2), SBE- 37 SMP ODO; RBR bottom pressure recorder (BPR); WetLabs fluorometer/turbidity optical sensor, FLNTU; Woods Hole Oceanographic Institution (WHOI) acoustic micro-modem. The corners of the BSP4 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.

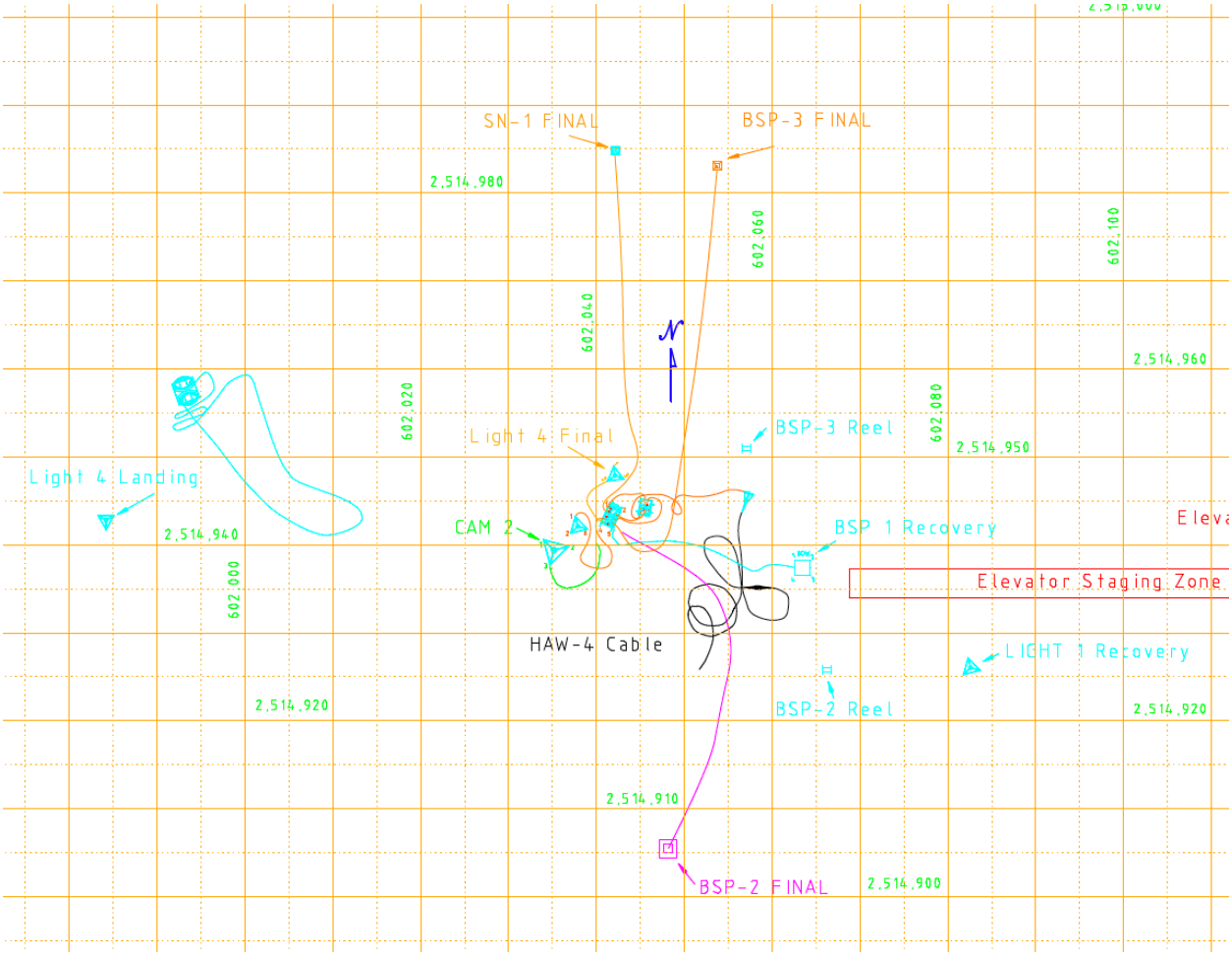

Figure 3-1 ACO Layout intended at end of cruise 2019 (BSP3 will be recovered).

Figure 3-2 BSP4 with CTDO2, FLNTU, RBR pressure, WHOI micromodem, and SIIM.

Figure 3-3 Sonar bell passive beacon, 200 mm dia. This will be on BSP4 parking stand/

Lastly, a "SonarBell" will be deployed (Figure 3-6). It is a 200-mm plastic sphere (filled with pressure balanced fluid) passive sonar target tuned for the ROV scanning sonar frequency (325 kHz). It will be on a 2-m mooring, deployed from the ROV basket at the cable termination.

4. Kauai Cable

The ATOC Kauai cable was laid in 1993, Figure 4.1. The nearshore section suffered a fault in summer 2017. To better localize the faulted section of cable, we will bring it on board the ship (using the ROV), cut it (~100 m water depth) and test both ends. If there is time, sections of the cable will be inspected with the ROV and the HX-554 acoustic source also inspected (at 810 m water depth). More detail is in the accompanying plan.

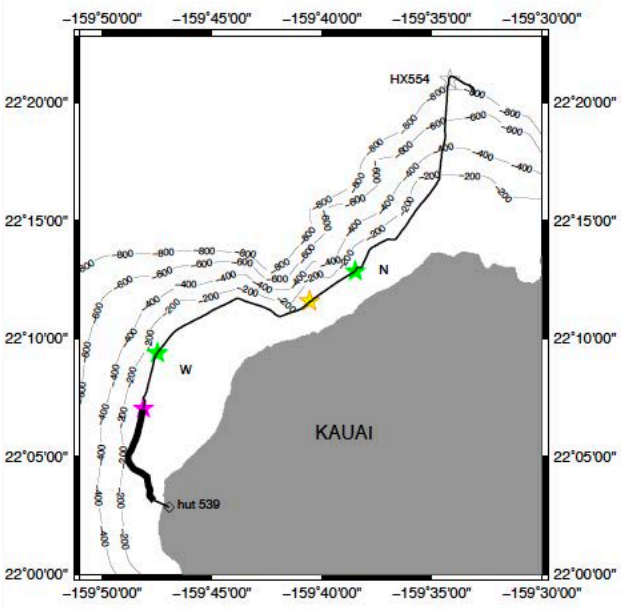

Figure 4-1 Kauai Cable. We will cut and test at the green star N.

5. ROV and TMS

ROV *Lu`ukai* is a two-body ROV system (Figure 5-1). 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.

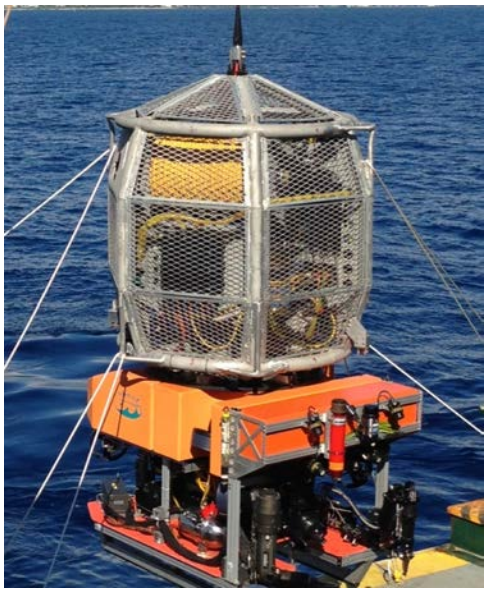

Figure 5-1 TMS and ROV.

6. 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 be calibrated as the first step at Station ALOHA, using the beacons deployed on BSP4 and ELEV.

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). Beacon 3 will be on the ELEVATOR and beacon 4 on the packages; one beacon will have to be either acquired or borrowed. Absolute geographical position is provided by the ship's POS-MV system using Fugro GPS with decimeter accuracy.

Figure 6-1 USBL Wideband Mini Transponder (WMT) – 7000 m

7. 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.

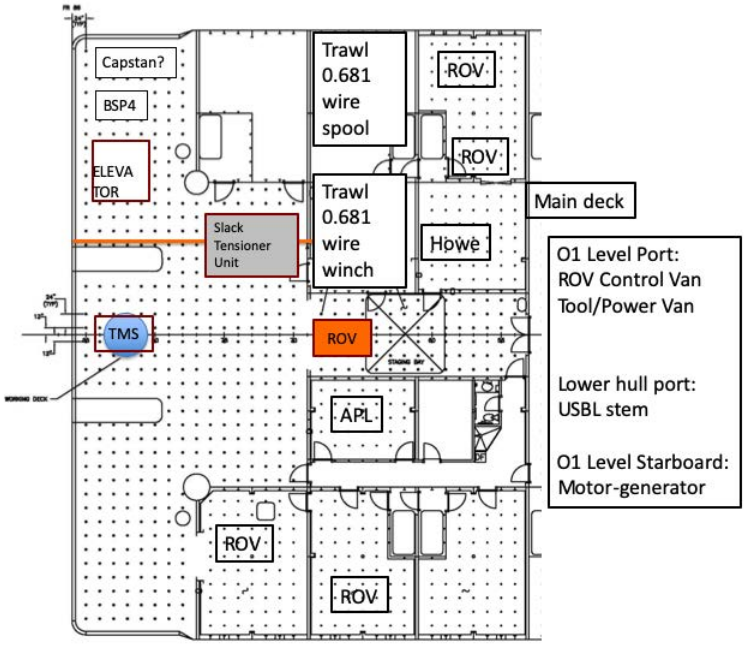

Figure 7-1 Main deck layout

8. Mobilization

The ROV will be mobilized 5-8 July. The ACO and Cable gear will have to be loaded on the ship including: BSP4, ELEVATOR, bench node for OBS, extra weights, tools, the balance of the RAP gear (in computer lab), and the Cable gear including lab electronics and recovery/deployment gear.

9. 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.

The APL team is responsible for all cable grips, gear for splicing, test gear, etc.

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, BSP2, BSP4 and recovering the ELEVATOR with LIGHT1, CAM2, and BSP2.

ACO will supply pin-protecting dummies for ODI connectors, with ROV mating provision (i.e., T-Handle, in-basket jig). APL will provide a cable/hose “guide” tool.

ACO will provide snap hooks/carabiners and line for ELEV use.

ACO will provide a “dumb” dummy/resistive load port test tool to test SN1 ports.

ROV will provide cutting tools, i.e., sharp knives and garden shears for line, bungies, tie wraps, in the “tool box” in the basket. One cutting tool with protected blade inside a “c”.

OTG will provide one USBL beacon on loan from MBARI for the TMS, and a OTG beacon for the ROV, so that each vehicle has a beacon. One beacon on LIGHT4 will be recovered and new batteries installed for subsequent use. One additional OTG beacon will be available for use on BSP3 and SN1.

OTG will assure absolutely best post positioning of 3.5 kHz transducer with the POS-MV system for RAP measurements (10 Hz, “sensor1” and “sensor2” and NEMA strings?)

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 acoustic Doppler current profiler data/plots (using 38 kHz and 300 kHz instruments), two air tuggers, and pallet jack. ADCP data processed in near-real time to determine currents affecting free fall instruments.

10. Operations and timeline

See Table 10.1 for a summary of tasks and times, and Appendix D for a detailed version.

BSP4 and ELEV will be deployed first. Using the beacons on the two packages, a “Casius” procedure will be used to survey in their positions, and the ship ultra-short baseline transducer attitude (especially the azimuth). Then, after the ROV is deployed, BSP4 will be moved and plugged into E1. ELEV will be found and moved next to BSP2, and the two released and recovered using the ship’s boat (in daylight). During this process the memorial plaque for Fred Duennebier will be recovered (about 215 m NW of the Cable Termination) and placed in view of CAM1. Also, BSP2 repair will begin on the ship. ELEV will be dropped again to recover CAM2 (with boat ops in daylight). ELEV and BSP2 will be deployed and BSP2 reconnected, now to SN1. ELEV will be moved to BSP3 and recovered. ELEV will be deployed and LIGHT1 connected, and recovered (again in daylight). Finally housekeeping tasks will be performed. In all, this plan calls for 1 ROV dive lasting several days, and 4 elevator cycles.

During the free fall of packages, we want to monitor drop and landing positions and ADCP near surface and bottom (from ACO) velocities to better estimate currents and so that we can better estimate drop locations and have the packaged land where desired.

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 (All shore personnel should have updated AT&T documents). Good communications are essential. We will try controlling the ACO from a ship-based computer (connected to Internet via the HiSeas network), to the extent of turning ports on and off.

During the entire cruise, in the vicinity of ALOHA, RAP acoustic transmissions will be made as done on previous cruises. Between ROV dives and whenever possible, the ship will move off and make measurements along radial, circular, and rectangular paths. Total estimated time for the ROV in the water is 84 hours, with most the bottom in 1 dive.

	Task	Start	hh:mm	End
1	Transit to test site - Ballast/trim dive	07/09 00:00	4:30	07/09 04:30
2	Transit to Station ALOHA	07/09 04:30	11:30	07/09 16:00
3	Deploy and Survey ELEV and BSP4	07/09 16:00	9:30	07/10 01:30
4	ROV Dive 1 (LK-112), Find BSP4	07/10 01:30	5:27	07/10 06:57
5	Find, move, and connect BSP4	07/10 06:57	5:55	07/10 12:52
6	Move BSP2 to ELEV and recover	07/10 12:52	6:15	07/10 19:07
7	Find and move Fred's plaque	07/10 19:07	2:40	07/10 21:47
8	Deploy ELEV and Recover CAM2	07/10 21:47	10:05	07/11 07:52
9	Deploy ELEV and repaired BSP2	07/11 07:52	3:25	07/11 11:17
10	Find, move, and connect BSP2	07/11 11:17	6:15	07/11 17:32
11	Recover BSP3	07/11 17:32	14:45	07/12 08:17
12	Deploy ELEV and Recover LIGHT1	07/12 08:17	7:05	07/12 15:22
13	Housekeeping and Final steps	07/12 15:22	26:40	07/13 18:02
14	Ascent and Recovery - end of Dive 1 (LK-112)	07/13 18:02	2:50	07/13 20:52
15	Contingency - ACO portion of cruise	07/13 20:52	15:08	07/14 12:00
16	Transit, Prepare for next dive; Kauai Cable	07/14 12:00	11:00	07/14 23:00
17	ROV Dive 2 (LK-113), Kauai Cable - Find and recover	07/14 23:00	17:00	07/15 16:00
18	ROV Dive 3 (LK-114), Kauai Cable - Post-deplyment inspection	07/15 16:00	5:00	07/15 21:00
19	Prepare for next dive; Kauai package	07/15 21:00	2:00	07/15 23:00
20	ROV Dive 4 (LK-115), Inspect Kauai Package	07/15 23:00	4:55	07/16 03:55
21	Contingency - Kauai Cable portion of cruise	07/16 03:55	0:15	07/16 04:10
22	Transit from Kauai Cable to Honolulu	07/16 04:10	13:50	07/16 18:00
			186:00	

Table 10-1 Cruise tasks and times (local HST time)

References

2011 cruise plan
http://aco-ssds.soest.hawaii.edu/ACO/docs/20110515_KM1116_Cruise_Plan_Howe_lo-res.pdf
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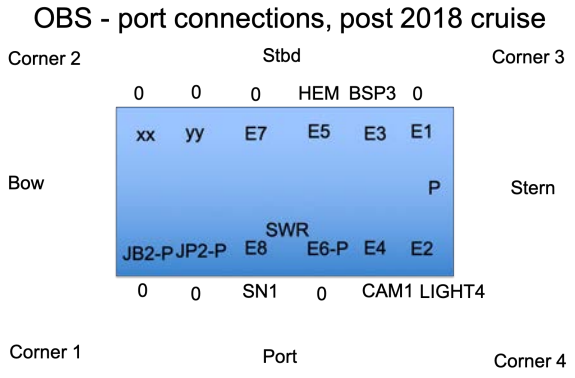
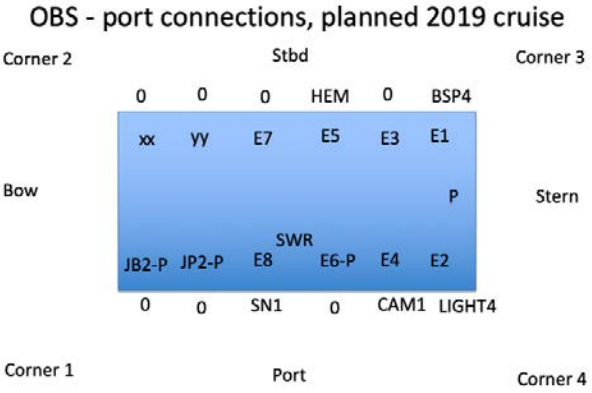
Oceans 11 paper
Howe, B. M., R. Lukas, F. Duennebier, and D. Karl, ALOHA cabled observatory installation, *OCEANS 2011*, 19-22 Sept. 2011, URL:
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6107301&isnumber=6106891
or
http://aco-ssds.soest.hawaii.edu/Howe_et_al_ACO_Oceans11.pdf

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.





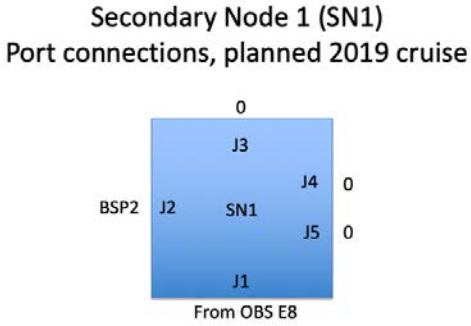


Figure A-1 ACO Observatory port connections – present and new (P = parking)

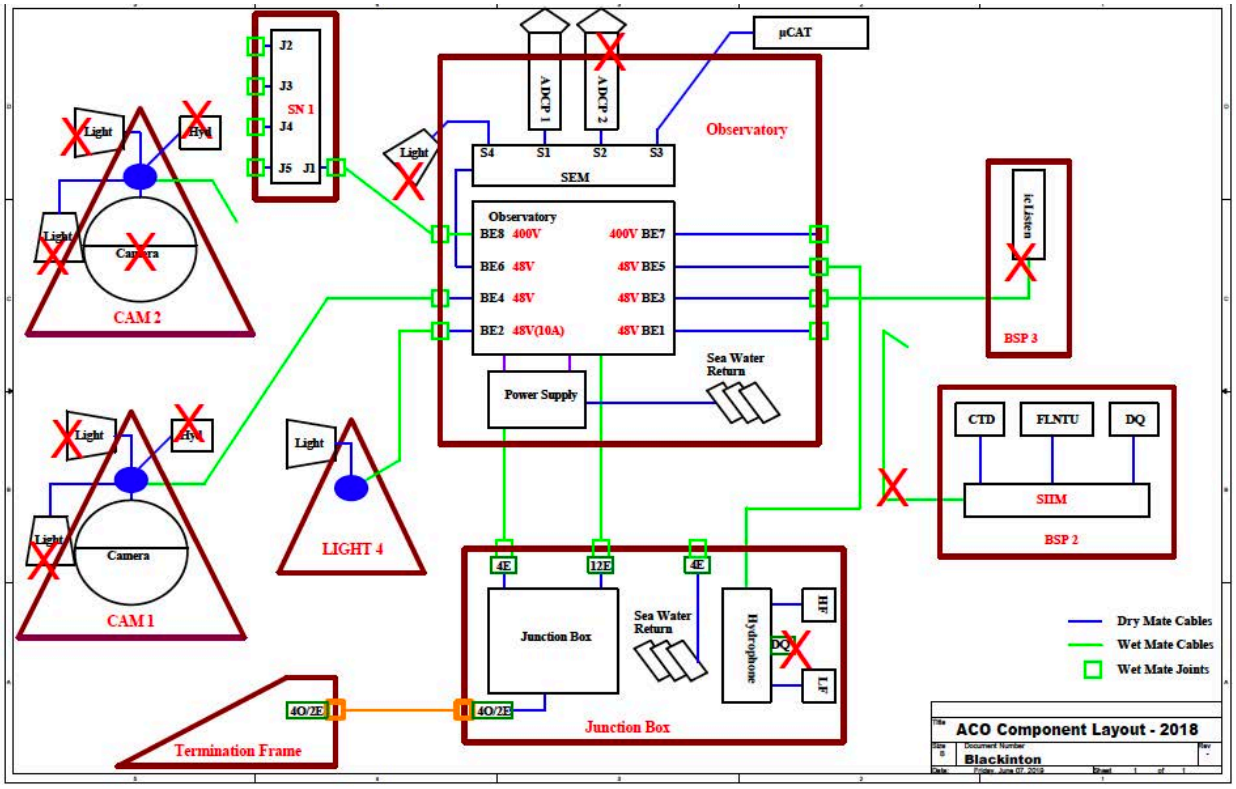


Figure A-2 ACO connections – June 2018; x = failed

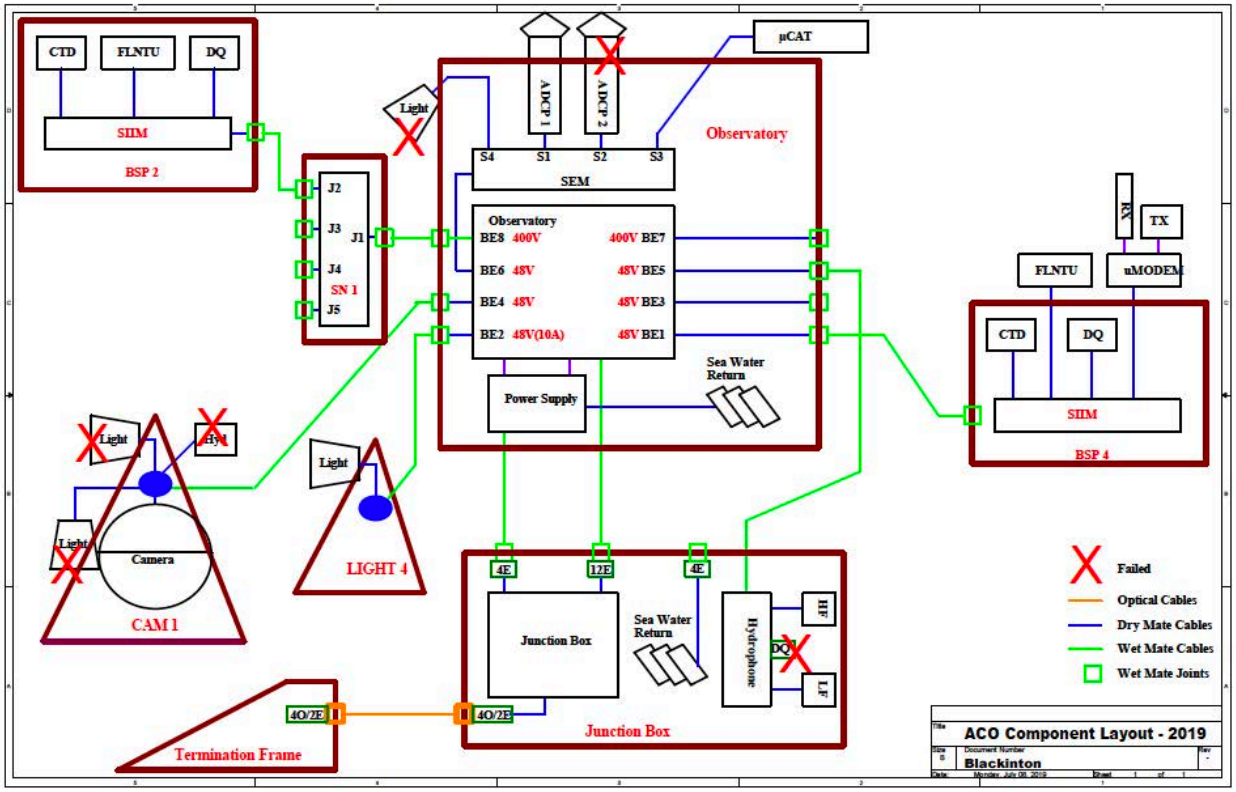


Figure A-3 Planned ACO connections – July 2019; x = failed

Appendix B – ACO Operations

The following table gives the detailed ACO tasks associated with deploying and recovering the instrumentation. Time is local HST.

			HST (UTC-10)	
	Fred = Fred's Memorial Plaque	**07/09 00:00**		**07/16 17:59**
	Task	**Start**	**hh:mm**	**End**
1	**Transit to test site - Ballast/trim dive**			
1	Transit from Honolulu Pier 35 to Shallow site	07/09 00:00	2:30	07/09 02:30
2	Perform ballast/trim operation (ROV in water, out) dive LK-111, water depth 430 m	07/09 02:30	2:00	07/09 04:30
3	Proceed to Station ALOHA	07/09 04:30	0:00	07/09 04:30
2	**Transit to Station ALOHA**			
1	Transit to Station ALOHA	07/09 04:30	11:00	07/09 15:30
2	Establish DP position (A-frame of ship) ~100 m E of the Cable Termination (CT)	07/09 15:30	0:30	07/09 16:00
3	**Deploy and Survey ELEV and BSP4**			
1	Deploy ELEV 210 m NE of CT per ROV nav. ELEV with USBL beacon, flasher, radio, acoustic release (where SN1 was - so near Fred); log USBL data for drop/current analysis	07/09 16:00	0:15	07/09 16:15
2	Move 150 m E of CT	07/09 16:15	0:30	07/09 16:45
3	Deploy BSP4, with parking position and SonarBell	07/09 16:45	0:15	07/09 17:00
4	Track packages to bottom, moving to 5 km E of CT. Note packages position(t) and estimate currents(z), and depth averaged current	07/09 17:00	1:30	07/09 18:30
5	Perform USBL survey per Casius plan, at 5 cardinal points (need more detail)	07/09 18:30	6:30	07/10 01:00
6	Complete survey over BSP4, into DP	07/10 01:00	0:30	07/10 01:30
4	**ROV Dive 1 (LK-112), Find BSP4**			
1	Deploy ROV (pint lid markers, tools)	07/10 01:30	0:03	07/10 01:33
2	In water, lines clear	07/10 01:33	0:03	07/10 01:36
3	At 100 m testing	07/10 01:36	0:20	07/10 01:56
4	At 500 m testing	07/10 01:56	0:10	07/10 02:06
5	continue to 1000 m at 30 m/min	07/10 02:06	0:19	07/10 02:25

	6	at 1000 m testing	07/10 02:25	0:05	07/10 02:30
	7	continue to 2000 m at 30 m/min	07/10 02:30	0:36	07/10 03:06
	8	At 2000 m testing	07/10 03:06	0:03	07/10 03:09
	9	Continue to 3000 m at 30 m/min	07/10 03:09	0:37	07/10 03:46
	10	At 3000 m testing	07/10 03:46	0:05	07/10 03:51
	11	Continue to 4000 m at 30 m/min	07/10 03:51	0:38	07/10 04:29
	12	At 4000 m testing	07/10 04:29	0:04	07/10 04:33
	13	Continue to 4650 m at 25 m/min	07/10 04:33	0:25	07/10 04:58
	14	At 4650 m moving to bottom work area	07/10 04:58	0:46	07/10 05:44
	15	Moving to target-BSP4. Undock and rotate ROV to scan sonar, redock	07/10 05:44	0:05	07/10 05:49
	16	Move to target-BSP4	07/10 05:49	0:02	07/10 05:51
	17	Lower TMS to 4683 m, 50 m off bottom	07/10 05:51	0:12	07/10 06:03
	18	Continue	07/10 06:03	0:10	07/10 06:13
	19	Continue to move to target-BSP4 docked in TMS	07/10 06:13	0:08	07/10 06:21
	20	Visual on BSP4	07/10 06:21	0:14	07/10 06:35
	21	BSP4 in view	07/10 06:35	0:02	07/10 06:37
	22	Undock, depth 4683 m	07/10 06:37	0:20	07/10 06:57
5	**Find, move, and connect BSP4**				
	1	Go to BSP4	07/10 06:57	0:20	07/10 07:17
	2	Remove BSP4 descent weight, leave paint lid marker	07/10 07:17	0:30	07/10 07:47
	3	Put BSP4 loop on horn	07/10 07:47	0:10	07/10 07:57
	4	Move BSP4 to position 47 m S from OBS Port E1 (SE corner)	07/10 07:57	1:00	07/10 08:57
	5	Set BSP4 down and uncouple	07/10 08:57	0:10	07/10 09:07
	6	Lift off parking position with SonarBell and set down	07/10 09:07	0:15	07/10 09:22
	7	Lift off hose reel and attach to ROV basket	07/10 09:22	0:15	07/10 09:37
	8	Move to OBS to connect, by E1, ship moving as necessary	07/10 09:37	0:45	07/10 10:22
	9	Set down reel, disconnect hose	07/10 10:22	0:15	07/10 10:37
	10	Remove pin-protecting dummy from end of hose, and	07/10 10:37	0:15	07/10 10:52
	11	Connect to E1	07/10 10:52	0:15	07/10 11:07
	12	Using hose tool, move hose in desired direction	07/10 11:07	0:15	07/10 11:22
	13	Go to end of hose/parking stand, pull slack (Yale grip 2 m from ODI connector)	07/10 11:22	0:15	07/10 11:37
	14	Reposition BSP4 next to parking frame	07/10 11:37	0:15	07/10 11:52

	15	Move connector from parking to BSP4	07/10 11:52	0:15	07/10 12:07
	16	Turn on E1 BSP4 and test	07/10 12:07	0:15	07/10 12:22
	17	Lift instrument masts into place	07/10 12:22	0:15	07/10 12:37
	18	Trim BSP4 and parking frame (with SonarBell/float), remove beacon, put in basket; note range,bearing to all objects; rationalize navigation. Parking frame remains.	07/10 12:37	0:15	07/10 12:52
6	**Move BSP2 to ELEV and recover**				
	1	Move to ELEV	07/10 12:52	0:15	07/10 13:07
	2	Remove descent weights	07/10 13:07	0:15	07/10 13:22
	3	Place marker	07/10 13:22	0:15	07/10 13:37
	4	Put loop on horn	07/10 13:37	0:15	07/10 13:52
	5	Move ELEV to BSP2	07/10 13:52	1:20	07/10 15:12
	6	Set ELEV down next to BSP2	07/10 15:12	0:10	07/10 15:22
	7	Connect BSP2 to ELEV	07/10 15:22	0:10	07/10 15:32
	8	Move ELEV away from BSP2 to tauten line	07/10 15:32	0:10	07/10 15:42
	9	Dress package, put beacon from BSP4 into spare holster on ELEV (BSP2 holster loose). Follow BSP2 to end to be sure clear.	07/10 15:42	0:30	07/10 16:12
	10	Dock ROV and move up and away upcurrent so packages just in view	07/10 16:12	0:10	07/10 16:22
	11	Release ELEV with acoustic command from ship (deck unit, over-the-side transducer prep beforehad)	07/10 16:22	0:15	07/10 16:37
	12	Watch package move up and away	07/10 16:37	0:05	07/10 16:42
	13	Track package and calculate current(z)	07/10 16:42	1:10	07/10 17:52
	14	To extent possible, ROV can start on Fred or other housekeeping tasks while package is ascending	07/10 17:52	0:00	07/10 17:52
	15	When packages surface note positions to get depth averaged currents; merge with other data	07/10 17:52	0:05	07/10 17:57
	16	Launch small boat (with GPS unit recording data) - should do this earlier when packages at 800 m, before ELEV surfaces	07/10 17:57	0:15	07/10 18:12
	17	Bring packages to ship and pass line	07/10 18:12	0:20	07/10 18:32
	18	Bring packages on ship	07/10 18:32	0:20	07/10 18:52
	19	Recover small boat	07/10 18:52	0:15	07/10 19:07

	20	Begin repair of BSP2 (remove old hose; uses test connector? attach replacemnt flying lead on 50 m hose on reel; replace CTD; test all)	07/10 19:07	0:00	07/10 19:07
7	**Find and move Fred's plaque**				
	1	If feasible given package trajectory and Fred's position, move ship and/or ROV to Fred during ELEV ascent and recovery (or ROV rests now)	07/10 19:07	1:00	07/10 20:07
	2	Undock ROV, Place marker; Pick up Fred	07/10 20:07	0:15	07/10 20:22
	3	Set Fred by CAM1 to be visible (by CAM1 leg away from OBS); position sponsor sign better	07/10 20:22	0:30	07/10 20:52
	4	Recover BSP4 hose reel (to put on CAM2)	07/10 20:52	0:45	07/10 21:37
	5	Dock ROV	07/10 21:37	0:10	07/10 21:47
8	**Deploy ELEV and Recover CAM2**				
	1	Move ship to ELEV deployment position (based on best current estimates) (with beacon for CAM2)	07/10 21:47	0:30	07/10 22:17
	2	Deploy ELEV and track down	07/10 22:17	0:20	07/10 22:37
	3	Move ROV to CAM2 (before/while ELEV descending); undock	07/10 22:37	0:20	07/10 22:57
	4	Attach hose reel to CAM2; Secure CAM2 hose to holster/frame; place marker	07/10 22:57	0:20	07/10 23:17
	5	Put CAM2 loop on horn; dock	07/10 23:17	0:15	07/10 23:32
	6	Coordinate ship/ROV to approach predicted ELEV touchdown point (with clearnace!)	07/10 23:32	0:30	07/11 00:02
	7	ELEV touchdown	07/11 00:02	0:00	07/11 00:02
	8	Bring CAM2 to ELEV	07/11 00:02	1:00	07/11 01:02
	9	Connect CAM2 to ELEV	07/11 01:02	0:15	07/11 01:17
	10	Pull connecting line taut	07/11 01:17	0:15	07/11 01:32
	11	Trim packages, put beacon on CAM2; place marker	07/11 01:32	0:30	07/11 02:02
	12	Rest and/or housekeeping, time package release so small boat launch at dawn	07/11 02:02	3:00	07/11 05:02
	13	Dock ROV and move up and away upcurrent so packages just in view	07/11 05:02	0:15	07/11 05:17
	14	Release ELEV with acoustic command from ship	07/11 05:17	0:15	07/11 05:32
	15	Watch package move up and away	07/11 05:32	0:05	07/11 05:37
	16	Track package and calculate current(z)	07/11 05:37	1:00	07/11 06:37

	17	To extent possible, ROV can contiue housekeeping tasks while package is ascending	07/11 06:37	0:00	07/11 06:37
	18	When packages surface note positions to get depth averaged currents; merge with other data	07/11 06:37	0:05	07/11 06:42
	19	Launch small boat (could be before ELEV surfaces (can start this earlier, as long as after sunrise at 0557)	07/11 06:42	0:15	07/11 06:57
	20	Bring packages to ship and pass line	07/11 06:57	0:20	07/11 07:17
	21	Bring packages on ship	07/11 07:17	0:20	07/11 07:37
	22	Recover small boat	07/11 07:37	0:15	07/11 07:52
9	**Deploy ELEV and repaired BSP2**				
	1	Deploy ELEV x m E of CT per ROV nav. With USBL beacon (only 1, not needed for LIGHT1), flasher, radio, acoustic release and bait fish	07/11 07:52	0:40	07/11 08:32
	2	Move 50 m E	07/11 08:32	0:30	07/11 09:02
	3	Deploy BSP2	07/11 09:02	0:15	07/11 09:17
	4	Track packages to bottom. Note position(t) and estimate currents(z), and depth averaged current	07/11 09:17	1:00	07/11 10:17
	5	Coordinate ship/ROV to approach predicted BSP2 touchdown point	07/11 10:17	0:30	07/11 10:47
	6	Move ROV to BSP2	07/11 10:47	0:30	07/11 11:17
10	**Find, move, and connect BSP2**				
	1	Find BSP2	07/11 11:17	0:30	07/11 11:47
	2	Remove descent weight, leave marker	07/11 11:47	0:20	07/11 12:07
	3	Put BSP2 loop on horn	07/11 12:07	0:15	07/11 12:22
	4	Move BSP2 to position 47 m W of SN1	07/11 12:22	1:00	07/11 13:22
	5	Set BSP2 down and uncouple	07/11 13:22	0:15	07/11 13:37
	6	x	07/11 13:37	0:15	07/11 13:52
	7	Lift off hose reel and attach to ROV basket	07/11 13:52	0:15	07/11 14:07
	8	Move to SN1 to connect, paying out hose	07/11 14:07	0:30	07/11 14:37
	9	Set down reel, disconnect hose	07/11 14:37	0:15	07/11 14:52
	10	Pick up SN1 to straighten/tauten hose back to OBS, hose out straight to OBS (recall though loop/near-kink in hose near OBS)	07/11 14:52	0:15	07/11 15:07
	11	Pick up connector on end of hose from BSP2 (just taken off reel), remove dummy	07/11 15:07	0:20	07/11 15:27

	12	Connect to J2 (on West side of SN1) (first remove environmental cover if one on J2)	07/11 15:27	0:15	07/11 15:42
	13	Pick up hose reel (to put on LIGHT1). Using hose tool, move hose in desired direction	07/11 15:42	0:15	07/11 15:57
	14	Go back to BSP2 guiding hose with tool	07/11 15:57	0:15	07/11 16:12
	15	Reposition BSP2 to just tauten hose	07/11 16:12	0:15	07/11 16:27
	16	x	07/11 16:27	0:15	07/11 16:42
	17	Turn on BSP2 and test	07/11 16:42	0:20	07/11 17:02
	18	Trim BSP2, remove beacon, put in basket; note range, bearing to all objects; rationalize navigation	07/11 17:02	0:30	07/11 17:32
11	**Recover BSP3**				
	1	Move ROV to OBS and disconnect BSP3 from E3	07/11 17:32	0:30	07/11 18:02
	2	Move ROV with BSP3 hose to BSP3 and place connector in holster/frame; put beacon in holster; place marker; also the hose reel if have one	07/11 18:02	0:40	07/11 18:42
	3	Put BSP3 loop on horn	07/11 18:42	0:15	07/11 18:57
	4	Bring BSP3 to ELEV	07/11 18:57	1:00	07/11 19:57
	5	Connect BSP3 to ELEV	07/11 19:57	0:15	07/11 20:12
	6	Pull connecting line taut; remove bait fish, put in basket	07/11 20:12	0:15	07/11 20:27
	7	Trim packages; place marker	07/11 20:27	0:30	07/11 20:57
	8	Rest, housekeeping, time package release so small boat launch at dawn	07/11 20:57	8:30	07/12 05:27
	9	Dock ROV and move up and away upcurrent so packages just in view	07/12 05:27	0:15	07/12 05:42
	10	Release ELEV with acoustic command from ship	07/12 05:42	0:15	07/12 05:57
	11	watch package move up and away	07/12 05:57	0:05	07/12 06:02
	12	Track package and calculate current(z)	07/12 06:02	1:00	07/12 07:02
	13	To extent possible, ROV can contiue housekeeping tasks while package is ascending	07/12 07:02	0:00	07/12 07:02
	14	When packages surface note positions to get depth averaged currents; merge with other data	07/12 07:02	0:05	07/12 07:07
	15	Launch small boat (could be before ELEV surfaces (can start this earlier, as long as after sunrise 0557)	07/12 07:07	0:15	07/12 07:22
	16	Bring packages to ship and pass line	07/12 07:22	0:20	07/12 07:42

	17	Bring packages on ship	07/12 07:42	0:20	07/12 08:02
	18	Recover small boat	07/12 08:02	0:15	07/12 08:17
12	**Deploy ELEV and Recover LIGHT1**				
	1	Move ship to ELEV deployment position (based on best current estimates) (with beacon for LIGH1)	07/12 08:17	0:30	07/12 08:47
	2	Deploy ELEV and track down	07/12 08:47	0:20	07/12 09:07
	3	Move ROV to LIGHT1 (before/while ELEV descending); undock	07/12 09:07	0:20	07/12 09:27
	4	Secure LIGHT1 hose to holster/frame; place marker	07/12 09:27	0:20	07/12 09:47
	5	Put LIGHT1 loop on horn; dock	07/12 09:47	0:15	07/12 10:02
	6	Coordinate ship/ROV to approach predicted ELEV touchdown point (with clearance!)	07/12 10:02	0:30	07/12 10:32
	7	ELEV touchdown	07/12 10:32	0:00	07/12 10:32
	8	Bring LIGHT1 to ELEV	07/12 10:32	1:00	07/12 11:32
	9	Connect LIGHT1 to ELEV	07/12 11:32	0:15	07/12 11:47
	10	Pull connecting line taut	07/12 11:47	0:15	07/12 12:02
	11	Trim packages, put beacon on LIGHT1; place marker	07/12 12:02	0:30	07/12 12:32
	12	Rest and/or housekeeping, time package release so small boat launch at dawn	07/12 12:32	0:00	07/12 12:32
	13	Dock ROV and move up and away upcurrent so packages just in view	07/12 12:32	0:15	07/12 12:47
	14	Release ELEV with acoustic command from ship	07/12 12:47	0:15	07/12 13:02
	15	Watch package move up and away	07/12 13:02	0:05	07/12 13:07
	16	Track package and calculate current(z)	07/12 13:07	1:00	07/12 14:07
	17	To extent possible, ROV can contiue housekeeping tasks while package is ascending	07/12 14:07	0:00	07/12 14:07
	18	When packages surface note positions to get depth averaged currents; merge with other data	07/12 14:07	0:05	07/12 14:12
	19	Launch small boat (could be before ELEV surfaces (can start this earlier, as long as after sunrise at 0557)	07/12 14:12	0:15	07/12 14:27
	20	Bring packages to ship and pass line	07/12 14:27	0:20	07/12 14:47
	21	Bring packages on ship	07/12 14:47	0:20	07/12 15:07
	22	Recover small boat	07/12 15:07	0:15	07/12 15:22

13	**Housekeeping and Final steps**				
	1	ROV returns to bottom (can happen while recovering ELEV on ship) and moves to LIGHT4; undock	07/12 15:22	0:15	07/12 15:37
	2	Adjust LIGHT4 and CAM1 as necessary based on directions from shore; place bait fish	07/12 15:37	2:00	07/12 17:37
	3	Fix tight loop in SN1 hose near OBS; readjust/move SN1 to new position; maximize distance given hose	07/12 17:37	2:00	07/12 19:37
	4	Re-adjust ACO sign	07/12 19:37	2:00	07/12 21:37
	5	Re-adjust Fred	07/12 21:37	1:45	07/12 23:22
	6	Dress all cables	07/12 23:22	3:40	07/13 03:02
	7	Clean SWR on W side of OBS	07/13 03:02	3:00	07/13 06:02
	8	Fly over each package to inspect; readjust position as required, and get good navigation fixes and photos	07/13 06:02	3:00	07/13 09:02
	9	Conduct a mow-the-lawn mosaic. Have camera looking as straight down as possible with no changes during mow and use constant altitude ROV mode	07/13 09:02	3:00	07/13 12:02
	10	Photo op - coordinate ROV Luukai and CAM1 control on shore	07/13 12:02	3:00	07/13 15:02
	11	Recover any remaining reels: one on basket, one reel held with Mantis; test ROV auto-track and any other features	07/13 15:02	3:00	07/13 18:02
14	**Ascent and Recovery - end of Dive 1 (LK-112)**				
	1	ROV ascends at 30 m/min	07/13 18:02	0:27	07/13 18:29
	2	Stop and test at 4000 m	07/13 18:29	0:00	07/13 18:29
	3	ROV ascends at 30 m/min	07/13 18:29	0:33	07/13 19:02
	4	Stop and test at 3000 m	07/13 19:02	0:00	07/13 19:02
	5	ROV ascends at 30 m/min	07/13 19:02	0:32	07/13 19:34
	6	Stop and test at 2000 m	07/13 19:34	0:00	07/13 19:34
	7	ROV ascends at 30 m/min	07/13 19:34	0:33	07/13 20:07
	8	Stop and test at 1000 m	07/13 20:07	0:00	07/13 20:07
	9	ROV ascends at 30 m/min	07/13 20:07	0:16	07/13 20:23
	10	Stop and test at 500 m	07/13 20:23	0:00	07/13 20:23
	10	ROV ascends at 30 m/min	07/13 20:23	0:20	07/13 20:43
	11	Recover ROV, on deck	07/13 20:43	0:09	07/13 20:52
15	**Contingency - ACO portion of cruise**				

	1	Contingency	07/13 20:52	15:08	07/14 12:00
	1	Contingency	07/14 12:00	0:00	07/14 12:00
16	**Transit, Prepare for next dive; Kauai Cable**				
	1	Prepare for next dive; ONR RAP work	07/14 12:00	0:00	07/14 12:00
	2	Transit to Kauai Cable	07/14 12:00	11:00	07/14 23:00
17	**ROV Dive 2 (LK-113), Kauai Cable - Find and recover**				
	1	Deploy ROV	07/14 23:00	0:10	07/14 23:10
	2	Descend to 50 m and start ROV, switch winch stations	07/14 23:10	0:20	07/14 23:30
	3	work to bottom, 100 m	07/14 23:30	0:30	07/15 00:00
	4	serach pattern	07/15 00:00	2:00	07/15 02:00
	5	attach line to Cable; leave markers	07/15 02:00	0:30	07/15 02:30
	6	bring to surface	07/15 02:30	0:30	07/15 03:00
	7	recover ROV, on deck	07/15 03:00	0:30	07/15 03:30
	8	cut Cable; start preping ends for splicing	07/15 03:30	0:30	07/15 04:00
	9	secure cable to ship	07/15 04:00	1:00	07/15 05:00
	10	Test seaward end (with acoustic source)	07/15 05:00	0:30	07/15 05:30
	11	Test shoreward end	07/15 05:30	0:30	07/15 06:00
	12	Repeat Test seaward end, source	07/15 06:00	2:00	07/15 08:00
	13	Repeat Test shoreward end	07/15 08:00	0:30	07/15 08:30
	14	Splice cable together	07/15 08:30	7:00	07/15 15:30
	15	Lower cable (acoustic release?)	07/15 15:30	0:30	07/15 16:00
18	**ROV Dive 3 (LK-114), Kauai Cable - Post-deplyment inspection**				
	16	Deploy ROV	07/15 16:00	0:30	07/15 16:30
	17	inspect toward shoreward end - leave markers, attach to cable	07/15 16:30	2:00	07/15 18:30
	18	inspect to seaward end - leave markers, attach to cables	07/15 18:30	2:00	07/15 20:30
	19	recover ROV, on deck	07/15 20:30	0:30	07/15 21:00
19	**Prepare for next dive; Kauai package**				
	1	Prepare for next dive transit to site	07/15 21:00	2:00	07/15 23:00
20	**ROV Dive 4 (LK-115), Inspect Kauai Package**				
	1	Deploy ROV	07/15 23:00	0:30	07/15 23:30
	2	In water, lines clear	07/15 23:30	0:05	07/15 23:35
	3	At 100 m testing	07/15 23:35	0:20	07/15 23:55
	4	At 500 m testing	07/15 23:55	0:20	07/16 00:15
	5	continue to 750 m at 30 m/min	07/16 00:15	0:20	07/16 00:35
	6	at 750 m testing	07/16 00:35	0:20	07/16 00:55
	7	Inspect package at 810 m depth	07/16 00:55	2:00	07/16 02:55

	8	Recover ROV, on deck	07/16 02:55	1:00	07/16 03:55
	9	TBD	07/16 03:55	0:00	07/16 03:55
21	**Contingency - Kauai Cable portion of cruise**				
	1	Contingency	07/16 03:55	0:15	07/16 04:10
	1	Contingency	07/16 04:10	0:00	07/16 04:10
22	**Transit from Kauai Cable to Honolulu**				
	1	Transit	07/16 04:10	12:00	07/16 16:10
	2		07/16 16:10	0:00	07/16 16:10
	2	At Honolulu buoy	07/16 16:10	1:00	07/16 17:10
	3	Arrive	07/16 17:10	0:50	07/16 18:00
			07/09 00:00	**186:00**	**07/16 17:59**

Table B-1 ACO tasks for deployment

Appendix C – Cruise Participants and Contacts List

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16	Julianna Diehl	Navigator		
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19	Riva Gulassa	Engineer/DOER		
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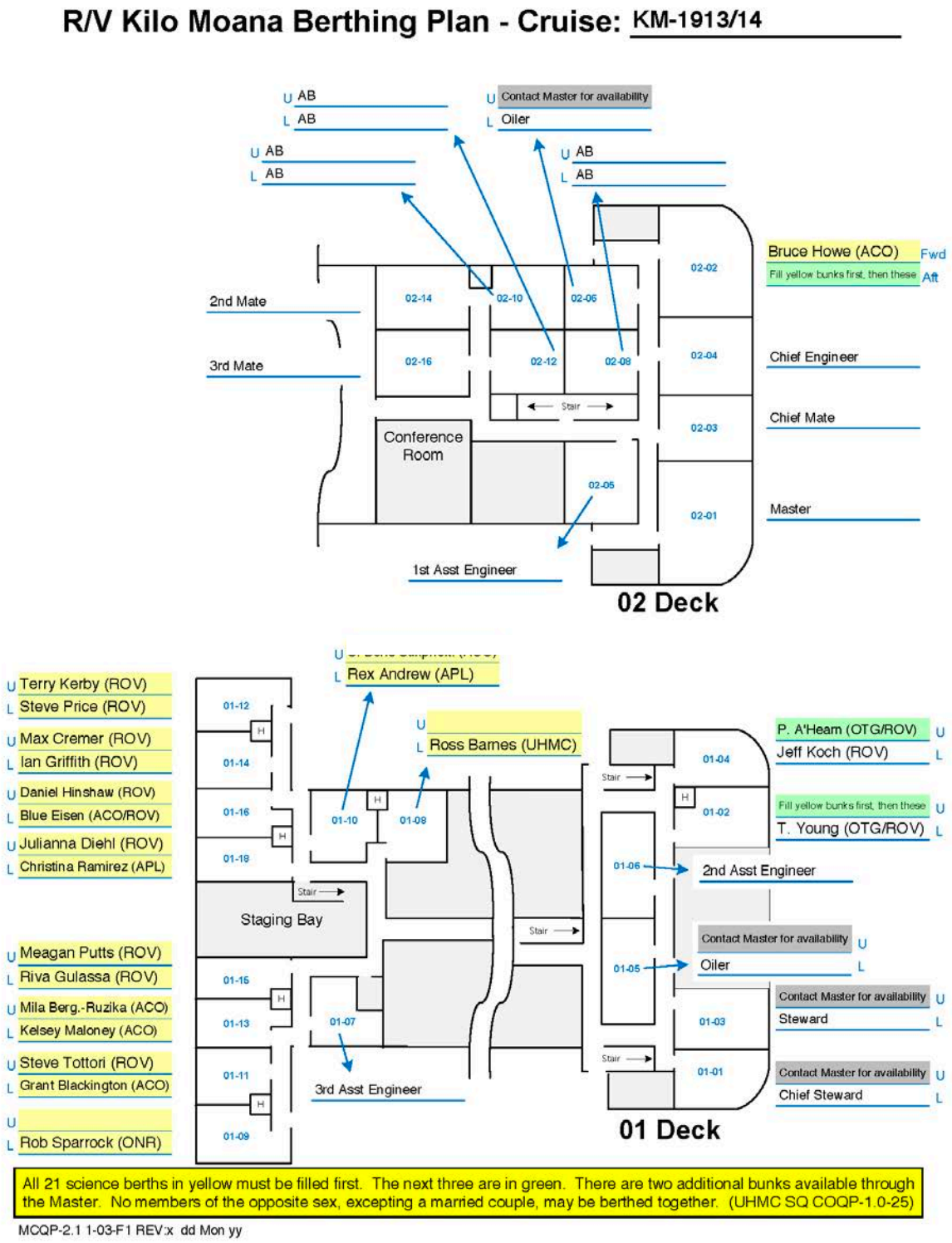
Appendix D – Berthing Plan



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
RAP	Reliable Acoustic Path
ROV	Remotely Operated Vehicle
SIIM	Science Instrument Interface Module
SMF	Single mode fiber
SN	Secondary Node
TF	Termination Frame