Cruise Report for R/V *Kilo Moana* KM-18-09:
ALOHA Cabled Observatory Service
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Summary

The purpose of this cruise on the R/V *Kilo Moana* was twofold: to service the instrumentation on the ALOHA Cabled Observatory (ACO), and secondarily, to collect acoustic travel time data (ship to ACO hydrophone) for the RAP (reliable acoustic path) tomography project. ACO is the deepest operating cabled observatory on the planet, at 4728 m water depth; it is supported by the National Science Foundation (NSF) and the University of Hawaii.

The ACO portion of the cruise was partially successful, limited by time (due to a late reduction in total ship days from 9 to 5). In the 4 days on station we accomplished the following ACO tasks: 1) deployed basic sensor package 3 (BSP3) with a broadband digital icListen hydrophone; 2) deployed secondary node 1 (SN1) to provide 4 additional ports; 3) connected LIGHT4 enabling camera 1 (CAM1); recovered basic sensor package 1 (BSP1); 4) "sank" to the seafloor basic sensor package 2 (BSP2; due to corrosion it had lost its ballast weight and was tethered only by its electrical cable to the Observatory; the electrical connection failed during the operation losing the pressure, fluorometer and CTD data streams). Due to time constraints we were not able to recover CAM2 or LIGHT1, or BSP2. Further, many smaller tasks were not completed, e.g., a plaque commemorating Fred Duennebier's life and pioneering role in ocean cable observatories was taken to the seafloor but we were not able to put it in view of the camera.

The ROV *Lu'ukai* proved very well that it now has the endurance to operate without technical fault for extended period. Three dives were conducted with one dive lasting 23 hours, with 17 hours on the bottom. However, its simple equipage slows operations.

During the cruise while over ACO, 3.5 kHz transmissions from the ship's echosounder were continuously collected on the ACO hydrophones for the RAP tomography project. Data were successfully collected while the ship was directly overhead during ROV operations, and between ROV dives when multiple patterns were run along circles, radials and "spin" points. The transmissions from the ship and receptions on the ACO hydrophone (and now icListen) are synchronized to ~1 microsecond; we are trying to determine accuracy of the ship/transducer position that we are achieving, with the end goal of being able separate position and timing from the sound speed variation that we are interested in. Details of this portion of the cruise will be reported elsewhere.

Introduction

Early in the planning process, the goals of the ACO portion were to plug in standalone LIGHT4 (so CAM1 could resume operation), install basic sensor package 3 (BSP3, with OceanSonics icListen hydrophone), install secondary node SN1, and to recover LIGHT1, CAM2, and BSP1 for service. A number of housekeeping tasks were also to be done. Two months before the cruise, BSP2 unexpectedly dropped its ascent weight because of corrosion, so was floating 50 m above the observatory, held down only by its oil filled hose connection. The first task of this

cruise then became to sink the BSP2 to the bottom and return it to operational status. The ACO work depended entirely on using the UH ROV *Lu'ukai*.

During the preceding cruise at the Clarion-Clipperton Fracture Zone (CCZ), Smith and Drazen used the ROV quite successfully, with all dives terminated because of science schedule considerations and not because of ROV technical issues. Most of the work consisted of "flying eyeball" video transects with some minimal sample collection. This was in contrast to the work on the ACO cruise which involved a combination of navigating, lifting, moving, orienting, and connecting packages.

A summary list of tasks is given in Table 1 with measures of success. Table 2 gives the summary timeline. A detailed log showing times and durations is given in Appendix A. Appendix B is a write up by Blue Eisen of the highlights of each operations with pictures; thus we only touch upon the high points here.

Task in order of priority	Success=1 Failure=0
Sink BSP2 – clear for ROV ops	1
Return BSP2 to operational status	0
Plug in LIGHT4	1
Restore CAM1	1
Deploy BSP3 icListen	1
Deploy SN1	1
Recover BSP1	1
Recover CAM2	0
Recover LIGHT1	0
Deploy sonar bell passive reflector	0
Deploy Fred's plaque	0
Clean sea electrode	0
Calibrate navigation system	0
Optimize LIGHT4 coverage	0
Recover BSP reels	0
Adjust ACO sign in view of camera	0
Dress seafloor cables	0
Photo op with ROV, CAM1, ACO	0
Construct mosaic of seafloor system	0

Table 1. Summary cruise tasks with success/failure indicated

The very first task of this cruise was to test *Lu'ukai* at 430 m just outside the harbor, to adjust the trim (a brow camera/light system and buoyancy had been removed after the last cruise). This was successfully completed.

Dive 1

The first task of Dive 1 was to reposition BSP2, by sinking it and bringing it back to its original bottom position. Very soon after work began on this, the electrical connection failed because the ROV holding onto the BSP2 frame tugged up on it. Sinking it to the seafloor was done using shot bags hung over the frame. While pulling it horizontally toward its original position, it was finally successfully stood upright on the bottom after 3.5 hours.

The LIGHT1 was cleared from the area and LIGHT4 retrieved and plugged in, taking 7.5 hours. Some seemingly simple tasks took a long time. A soft line had a loop on the end – it took an hour to open the loop to fit on the "horn" of the ROV, and finding LIGHT4 took 1.3 hours. This was an early indicator the navigation system had issues. Dive 1 was terminated after 12 hours on the

bottom, and 4.5 hour for descent and 2.5 hour for ascent for a total dive time of just under 19 hours.

Dive 2

The BSP3 and SN1 packages were deployed, and then the ROV. The first activities were to clear BSP1 and BPS2 hoses and connectors, taking 2.7 hours. BSP3 (icListen hydrophone) was then found, moved, and connected, taking 6.5 hour. Most of this was for moving first to find the unit (5 m/min, 0.15 kt), and then to move it to within 50 m of the OBS. The BSP3 icListen hydrophone is currently undergoing commissioning (partly us more completely understanding the complex unit).

The same steps were repeated for SN1, taking 6.3 hours. Moving to SN1 took 1.3 hours. Moving back toward the OBS (very close to BSP3) took 1 hour. Moving the OBS CTD mast out of the way to reach the connector took 1.5 hours. The entire dive took nearly 23 hours, with 17 hours on bottom. While there are no instruments yet plugged into SN1, all appears normal, and it expands the total number of wet-mate ports from 8 to 12. Of the 8 on the OBS, 6 are used for HEM (hydrophone), μSEM (with ADCP, CT), LIGHT4, CAM1, BSP3, SN1, leaving on 48 V port and 1 400 V port free.

			UTC HST+10	
	Task	Start	hh:mm	End
1	Transit to test site - Ballast/trim dive	06/18 10:00	3:12	06/18 13:12
2	Transit to Station ALOHA	06/18 13:12	15:26	06/19 04:38
3	ROV Dive 1 (LK-098), Find BSP2, LIGHTs	06/19 04:38	5:16	06/19 09:54
4	Re-Position BSP2	06/19 09:54	3:39	06/19 13:33
5	Move LIGHT1	06/19 13:33	2:24	06/19 15:57
6	Move and connect LIGHT4	06/19 15:57	5:11	06/19 21:08
7	Ascent and Recovery - end of Dive 1 (LK-098)	06/19 21:08	2:18	06/19 23:26
8	Prepare for next dive; ONR RAP work	06/19 23:26	12:08	06/20 11:34
9	ROV Dive 2 (LK-099), Deploy SN1 and BSP3	06/20 11:34	5:26	06/20 17:00
10	Deal with BSP2 and BSP1 connectors and hoses	06/20 17:00	2:38	06/20 19:38
11	Move and connect BSP3	06/20 19:38	6:33	06/21 02:11
12	Move and connect SN1	06/21 02:11	6:15	06/21 08:26
13	Ascent and Recovery - end of Dive 2 (LK-099)	06/21 08:26	2:39	06/21 11:05
14	Prepare for next dive; ONR RAP work	06/21 11:05	14:10	06/22 01:15
15	ROV Dive 3 (LK-100), Deploy ELEV, Recover BSP1	06/22 01:15	6:48	06/22 08:03
16	BSP2 weights, OBS CTD mast, ELEV-BSP1	06/22 08:03	6:46	06/22 14:49
17	Ascent and Recovery - end of Dive 3 (LK-100)	06/22 14:49	5:22	06/22 20:11
18	Transit to Haleiwa and Honolulu	06/22 20:11	14:49	06/23 11:00
			121:00	

Table 2. Summary cruise tasks and times (UTC; local HST time = UTC – 10)

Dive 3

As time was running short, and it had not been possible to move and position CAM2 and LIGHT1 for recovery, it was decided to just recover BSP1 with a direct connection between the

ELEV and BSP1. A 3 hour delay due to a broken winch level wind chain was incurred early in the descent. The ROV in this case quickly found the ELEV (20 minutes) and retrieved additional weights with chain for holding down the BSP2. After performing this task, the CTD mast on the OBS was flipped to its original position (it was now our single temperature sensor maintaining the 7+ year time series). After lowering the CTD and acoustic modem masts on the BSP1, a line was connected to its bale and moved to the ELEV. It was too short and another was added in series. This was finally connected but not without drama down to the last minute, trying to work the carabiner into a tight area. The entire dive took 15.7 hours.

When the ROV reached 500 m, the acoustic release was fired and the ELEV with BSP1 came to the surface and was recovered (took 2 tries of the ship going by the ELEV). BSP1 was connected to our bench node, but while drawing power, no communications were possible with the ethernet switch (contrary to before disconnection when we were still communicating with the SIIM and CTD).

Last steps

With BSP1 on deck, the ship headed to Haleiwa to drop B. Howe off to catch a flight, and then proceeded to the Honolulu sea buoy and then Pier 35.

Lessons and Concluding remarks

Besides connecting BSP3 and SN1, a major success was the ROV *Lu'ukai.* For the first time in 5 years (including the immediately preceding cruise), the ROV was able to perform dependably, without failures which would terminate dives. There is of course room for improvement.

We need, however, to improve the navigation system, both of the ROV by itself, and in concert with ACO. On multiple occasions we were unable to determine the location of the ROV with respect to ACO components. It is unclear what the problems were, but suspect that the following issues contribute:

1. The tracking head for the ultra-short baseline acoustic positioning system is retracted every time the ship needs to move at a significant speed. This happens during RAP operations and recovery operations. It is unknown how accurately the head is realigned when it is lowered to resume ROV operations. Further, the azimuthal angle of the head with respect to the ship heading needs calibration (using a fixed bottom mounted beacon).
2. We lack the knowledge of how to use the display software effectively to show moving objects on a prior map of bottom objects. We have been unsuccessful at generating a version of our ACO layout map that can be imported and displayed with the ROV measured positions. This requires time dedicated to extracting this information from the manufacture of the navigation package.
3. The scanning sonar itself is of poor quality. This could be simply display or hardware setup parameters.
4. Possible solutions to this moving/fixed object location problem could be a combination of:
    a. A prepared inventory of white paint bucket lids with unique ID to lay out on the bottom to provide points of reference.
    b. A permanently bottom mounted USBL transponder, with power from one of the ACO instrument ports that can be interrogated from the ship as are the beacons used to track instrument drops and recoveries.
    c. The sonar bell passive reflector(s), when installed will provide passive acoustic landmarks for the scanning sonar with a range that should be greater than the maximum distance across the ACO.
    d. Another possibility are light emitting ropes, connected, for instance, to unused SN1 ports, laid out in the cardinal directions.

Given the trouble we had gaining access to OBS ports and the close proximity of instruments to the OBS (CAM1, CAM2, LIGHT4, JBOX, etc.) we need to work towards having 50 m hoses (double end flying leads) attached to the OBS (and SN1) extending out evenly spaced azimuthally to instruments, thereby maximizing working space around each individual connector and instrument.

As new packages are developed, we need overall smaller packages (weight, volume, dimensions) with connectors lower down, to fit the capabilities of the ROV.

In cases with multiple dives, we need to make better estimates o of vertically integrated currents to then better estimate subsequent drop locations (as offsets were somewhat consistent on this cruise), to minimize time to move to packages on the bottom.

Better pre-cruise and pre-dive planning is needed. Better methods for handling lines, cables and connectors also need to be prepared. These methods need to reduce the level of skill in operating the manipulator arms of the ROV. The loss of BSP2 connectivity should not have happened. More attention to dissimilar metals and anchor materials (concrete?) is needed.

If a proposed short cruise happens in in the next few months, the balance of the tasks in Table 1 would be accomplished in the order given. We expect to be able to replace the hose on BSP2 and redeploy it on a following dive, bringing important pressure, CTDO2, and fluorometer data back on line. We would recover CAM2 and LIGHT1 and thereby finally begin to diagnose three failed Cathx lights.

CAM2, LIGHT1, and BSP4 (refreshed BSP1 sans ADCP) could be repaired and then deployed in June 2019. The long list of somewhat lower priority items would be addressed.

Additional and more detailed suggested improvements are given in Appendix B.

Acknowledgments

As is always the case in complex at-sea operations, many people contributed to the success.

We thank the captain Mike Hoshlyk and crew of the R/V *Kilo Moana* for their support during the cruise.

The *Lu'ukai* personnel led by Max Cremer are an excellent well integrated and cohesive team, very professionally and efficiently executing the necessary tasks.

Meagan Putts, NOAA, assisted with organizing the ROV video and other data, making it very easy to access and scan video still frames for events of interest.

The cruise and shore party participants are listed in Appendix C.

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Appendix A – Cruise timeline

	Task	Start (UTC (HST+10))	hh:mm	End
1	Transit to test site - Ballast/trim dive	06/18 10:00	3:12	06/18 13:12
2	Transit to Station ALOHA	06/18 13:12	15:26	06/19 04:38
3	ROV Dive 1 (LK-098), Find BSP2, LIGHTs	06/19 04:38	5:16	06/19 09:54
4	Re-Position BSP2	06/19 09:54	3:39	06/19 13:33
5	Move LIGHT1	06/19 13:33	2:24	06/19 15:57
6	Move and connect LIGHT4	06/19 15:57	5:11	06/19 21:08
7	Ascent and Recovery - end of Dive 1 (LK-098)	06/19 21:08	2:18	06/19 23:26
8	Prepare for next dive; ONR RAP work	06/19 23:26	12:08	06/20 11:34
9	ROV Dive 2 (LK-099), Deploy SN1 and BSP3	06/20 11:34	5:26	06/20 17:00
10	Deal with BSP2 and BSP1 connectors and hoses	06/20 17:00	2:38	06/20 19:38
11	Move and connect BSP3	06/20 19:38	6:33	06/21 02:11
12	Move and connect SN1	06/21 02:11	6:15	06/21 08:26
13	Ascent and Recovery - end of Dive 2 (LK-099)	06/21 08:26	2:39	06/21 11:05
14	Prepare for next dive; ONR RAP work	06/21 11:05	14:10	06/22 01:15
15	ROV Dive 3 (LK-100), Deploy ELEV, Recover BSP1	06/22 01:15	6:48	06/22 08:03
16	BSP2 weights, OBS CTD mast, ELEV-BSP1	06/22 08:03	6:46	06/22 14:49
17	Ascent and Recovery - end of Dive 3 (LK-100)	06/22 14:49	5:22	06/22 20:11
18	Transit to Haleiwa and Honolulu	06/22 20:11	14:49	06/23 11:00
			121:00	

		Task	UTC (HST+10) Start	hh:mm	End
			06/18 10:00		06/23 10:00
1		**Transit to test site - Ballast/trim dive**			
	1	Transit from Honolulu Pier 35 to Shallow site	06/18 10:00	1:59	06/18 11:59
	2	Perform ballast/trim operation (ROV in water, out)	06/18 11:59	1:13	06/18 13:12
	3	Proceed to Station ALOHA	06/18 13:12	0:00	06/18 13:12
2		**Transit to Station ALOHA**			
	1	Transit to Station ALOHA	06/18 13:12	10:18	06/18 23:30
	2	Load ROV basket: knives chisels for cleaning sea water return (SWR), 1 Environmental Cover (EC), 2 pin-protecting dummies with T-handle, extra weights for BSP2; pre-dive checks	06/18 23:30	4:42	06/19 04:12

	3	Establish DP position (A-frame of ship) ~50 m S of the Cable Termination (CT)	06/19 04:12	0:26	06/19 04:38
3	**ROV Dive 1 (LK-098), Find BSP2, LIGHTs**				
	1	Deploy ROV	06/19 04:38	0:03	06/19 04:41
	2	In water, lines clear	06/19 04:41	0:03	06/19 04:44
	3	winch issue, resolved, descend to 500 m at 25 m/min	06/19 04:44	0:29	06/19 05:13
	4	At 500 m testing	06/19 05:13	0:10	06/19 05:23
	5	continue to 1000 m at 30 m/min	06/19 05:23	0:19	06/19 05:42
	6	at 1000 m testing	06/19 05:42	0:05	06/19 05:47
	7	continue to 2000 m at 30 m/min	06/19 05:47	0:36	06/19 06:23
	8	At 2000 m testing	06/19 06:23	0:03	06/19 06:26
	9	Continue to 3000 m at 30 m/min	06/19 06:26	0:37	06/19 07:03
	10	At 3000 m testing	06/19 07:03	0:05	06/19 07:08
	11	Continue to 4000 m at 30 m/min	06/19 07:08	0:38	06/19 07:46
	12	At 4000 m testing	06/19 07:46	0:04	06/19 07:50
	13	Continue to 4650 m at 25 m/min	06/19 07:50	0:25	06/19 08:15
	14	At 4650 m moving to bottom work area, depth 4663 m, altitude 71 m	06/19 08:15	0:46	06/19 09:01
	15	At 4664 m moving N to target-BSP2. Undock and rotate ROV to scan sonar to N. Redock.	06/19 09:01	0:05	06/19 09:06
	16	Move NNW to target-BSP2	06/19 09:06	0:02	06/19 09:08
	17	Lower TMS to 4678 m, 55 m off bottom	06/19 09:08	0:12	06/19 09:20
	18	At 4683 m, contact at 48 m, 50 m off bottom	06/19 09:20	0:10	06/19 09:30
	19	Continue to move to target-BSP2 docked in TMS, 35 m from target	06/19 09:30	0:08	06/19 09:38
	20	Visual on BSP2	06/19 09:38	0:14	06/19 09:52
	21	BSP2 in view 15 m N	06/19 09:52	0:02	06/19 09:54
	22	Undock, depth 4683 m	06/19 09:54	0:00	06/19 09:54
4	**Re-Position BSP2**				
	1	Working with BSP2 to sink; steel ascent weights had rusted around titanium rod/washer/nut.	06/19 09:54	0:17	06/19 10:11
	2	Electrical failure of BSP2	06/19 10:11	0:22	06/19 10:33
	3	Mantis on rope of recovery line; Orion on top frame	06/19 10:33	0:17	06/19 10:50
	4	Moving down and S	06/19 10:50	0:16	06/19 11:06
	5	On bottom, applying weight to BSP2	06/19 11:06	0:49	06/19 11:55
	6	Secure BSP2 with 100 lb of shot bags. Dock.	06/19 11:55	0:16	06/19 12:11
	7	Undock. ROV to bottom	06/19 12:11	0:09	06/19 12:20

	8	T.A. Trim ROV by dropping 25 lb shot bag	06/19 12:20	0:10	06/19 12:30
	9	T.A. Dock, begin transit to E1 on OBS	06/19 12:30	0:25	06/19 12:55
	10	Undock and descend to work on BSP2 E1 connector	06/19 12:55	0:12	06/19 13:07
	11	Take BSP2 hose loop of light boom on OBS by E1, loop free	06/19 13:07	0:07	06/19 13:14
	12	Test BSP2 again by unplug/plugging into E1 and turning on power - not working - hose definitely bad	06/19 13:14	0:07	06/19 13:21
	13	Unplug BSP2 from E1 - dummy???	06/19 13:21	0:08	06/19 13:29
	14	Move to LIGHT1	06/19 13:29	0:04	06/19 13:33
5	**Move LIGHT1**				
	1	Move to LIGHT1, has pin protecting dummy, E side of OBS between corners 2 and 3;	06/19 13:33	0:00	06/19 13:33
	2	Pick up connector/yale grip??	06/19 13:33	0:10	06/19 13:43
	3	Move to LIGHT1 and place connector in holster and secure with bungie??	06/19 13:43	0:15	06/19 13:58
	4	On ROV "horn" (extreme difficulty getting squashed loop to open to fit over horn)	06/19 13:58	1:05	06/19 15:03
	5	Dock. Move LIGHT1 to "boneyard" 20 m E of BSP2 reel	06/19 15:03	0:52	06/19 15:55
	6	Place LIGHT1. 4732 m depth. Dock	06/19 15:55	0:02	06/19 15:57
6	**Move and connect LIGHT4**				
	1	Move ship and ROV via OBS to LIGHT4	06/19 15:57	0:39	06/19 16:36
	2	Undock and search for LIGHT4	06/19 16:36	0:36	06/19 17:12
	3	Located LIGHT4 at 4736 m.	06/19 17:12	0:00	06/19 17:12
	4	Remove beacon.	06/19 17:12	0:05	06/19 17:17
	5	Put beacon in basket	06/19 17:17	0:07	06/19 17:24
	6	Wait for cloud to clear	06/19 17:24	0:19	06/19 17:43
	7	Pull pin on weights	06/19 17:43	0:06	06/19 17:49
	8	Pull chain away from leg moving to top o frame (that is lying on bottom)	06/19 17:49	0:08	06/19 17:57
	9	Lifting line eye on horn	06/19 17:57	0:01	06/19 17:58
	10	ROV lifting LIGHT4, moving to near OBS. Undock	06/19 17:58	0:42	06/19 18:40
	11	Continue moving to OBS, set down	06/19 18:40	0:20	06/19 19:00
	12	Start pulling cable bungies off	06/19 19:00	0:13	06/19 19:13
	13	Connector out of holster, releasing pin-protecting dummy, move to OBS by E2.	06/19 19:13	0:12	06/19 19:25
	14	Remove CAM2 connector from E2	06/19 19:25	0:05	06/19 19:30

	15	Connect LIGHT4 to port E2 - works	06/19 19:30	0:11	06/19 19:41
	16	Plug CAM2 connector into pin-protecting dummy from holster with T-handle - broke	06/19 19:41	0:30	06/19 20:11
	17	Take CAM2 cable to CAM2	06/19 20:11	0:06	06/19 20:17
	18	CAM2 cable south of CAM2 now - NO dummy on	06/19 20:17	0:04	06/19 20:21
	19	Wait for sediment to clear	06/19 20:21	0:11	06/19 20:32
	20	Rotate LIGHT4 CCW to OBS	06/19 20:32	0:00	06/19 20:32
	21	Recovered two dummies: Dummy broken handle dropped on N side of LIGHT4. Dummy from LIGHT4 holster under frame with handle	06/19 20:32	0:19	06/19 20:51
	22	Docked, off bottom 4736 m depth, near LIGHT4	06/19 20:51	0:17	06/19 21:08
7	**Ascent and Recovery - end of Dive 1 (LK-098)**				
	1	ROV ascends at 30 m/min	06/19 21:08	0:27	06/19 21:35
	2	Stop and test at 4000 m	06/19 21:35	0:00	06/19 21:35
	3	ROV ascends at 30 m/min	06/19 21:35	0:18	06/19 21:53
	4	Stop and test at 3000 m	06/19 21:53	0:00	06/19 21:53
	5	ROV ascends at 30 m/min	06/19 21:53	0:32	06/19 22:25
	6	Stop and test at 2000 m	06/19 22:25	0:00	06/19 22:25
	7	ROV ascends at 30 m/min	06/19 22:25	0:16	06/19 22:41
	8	Stop and test at 1000 m	06/19 22:41	0:00	06/19 22:41
	9	ROV ascends at 30 m/min	06/19 22:41	0:16	06/19 22:57
	10	Stop and test at 500 m	06/19 22:57	0:00	06/19 22:57
	10	ROV ascends at 30 m/min	06/19 22:57	0:20	06/19 23:17
	11	Recover ROV, on deck	06/19 23:17	0:09	06/19 23:26
8	**Prepare for next dive; ONR RAP work**				
	1	Prepare for next dive; ONR RAP work	06/19 23:26	12:08	06/20 11:34
9	**ROV Dive 2 (LK-099), Deploy SN1 and BSP3**				
	1	Deploy BSP3 drop point 100 m N of CT. With USBL beacon and reel of hose. Has Fred's plaque	06/20 11:34	0:00	06/20 11:34
	1	Move ship to SN1 drop point	06/20 11:34	0:15	06/20 11:49
	2	Deploy SN1 free fall, SN1 with USBL Beacon 4, pin-protecting dummys on both flying connectors with pull-rope	06/20 11:49	0:00	06/20 11:49
	3	Move ship to ROV deployment position	06/20 11:49	0:36	06/20 12:25
	4	Deploy ROV	06/20 12:25	0:02	06/20 12:27
	5	Descend to 50 m and start ROV, switch winch stations	06/20 12:27	0:10	06/20 12:37

	6	continue to 500 m at 30 m/min	06/20 12:37	0:12	06/20 12:49
	7	SN1 on bottom - 79 m/min	06/20 12:49	0:11	06/20 13:00
	8	At 500 m testing	06/20 13:00	0:02	06/20 13:02
	9	continue to 1000 m at 30 m/min	06/20 13:02	0:10	06/20 13:12
	10	BSP3 on bottom - 48 m/min	06/20 13:12	0:08	06/20 13:20
	11	at 1000 m testing	06/20 13:20	0:05	06/20 13:25
	12	continue to 2000 m at 30 m/min	06/20 13:25	0:32	06/20 13:57
	13	At 2000 m testing	06/20 13:57	0:05	06/20 14:02
	14	Continue to 3000 m at 30 m/min	06/20 14:02	0:35	06/20 14:37
	15	At 3000 m testing	06/20 14:37	0:05	06/20 14:42
	16	Continue to 4000 m at 30 m/min	06/20 14:42	0:35	06/20 15:17
	17	At 4000 m testing	06/20 15:17	0:03	06/20 15:20
	18	Continue to 4600 m at 25 m/min	06/20 15:20	0:20	06/20 15:40
	19	At 4675 m, turn over to bottom work crew	06/20 15:40	0:04	06/20 15:44
	20	Continue to 4715 m, stop, over OBS (could see light about 40 m distant)	06/20 15:44	0:39	06/20 16:23
	21	Undock near OBS very near LIGHT4	06/20 16:23	0:03	06/20 16:26
	22	On bottom, dumping shot bags to trim	06/20 16:26	0:15	06/20 16:41
	23	Move to E1 on OBS to test	06/20 16:41	0:19	06/20 17:00
10	**Deal with BSP2 and BSP1 connectors and hoses**				
	1	Take out BSP2 connector from E1 and plug in power load test tool	06/20 17:00	0:22	06/20 17:22
	2	Test E1 power - V=49.13V, I=1.022A - correct	06/20 17:22	0:02	06/20 17:24
	3	Connect BSP2 to pin protecting dummy	06/20 17:24	0:34	06/20 17:58
	4	Put yale grip loop on horn	06/20 17:58	0:07	06/20 18:05
	5	Move to BSP2 and release connector	06/20 18:05	0:08	06/20 18:13
	6	Wait for cloud to clear	06/20 18:13	0:09	06/20 18:22
	7	Yale grip hooked on BSP2 frame	06/20 18:22	0:00	06/20 18:22
	8	Move to E3	06/20 18:22	0:05	06/20 18:27
	9	Remove BSP1 connector from E3	06/20 18:27	0:06	06/20 18:33
	10	Pick up dummy, remove rubber band	06/20 18:33	0:04	06/20 18:37
	11	Try to put connector on horn, settel for in basket	06/20 18:37	0:08	06/20 18:45
	12	Move to BSP1	06/20 18:45	0:06	06/20 18:51
	13	Trying to get connector in holster, many efforts, finnally, but give up trying bungie.	06/20 18:51	0:43	06/20 19:34
	14	Dock, prepare to move to BSP3	06/20 19:34	0:04	06/20 19:38
11	**Move and connect BSP3**				
	1	Moving to BSP3, ship over BSP3	06/20 19:38	0:22	06/20 20:00
	2	BSP3 in sight	06/20 20:00	0:30	06/20 20:30

3	Transit complete, 5 m/min, 0.14 kt	06/20 20:30	0:03	06/20 20:33
4	At BSP3, undock	06/20 20:33	0:03	06/20 20:36
5	At BSP3, Fred's plaque uner frame	06/20 20:36	0:04	06/20 20:40
6	Pull release for chain, dropped "lawn dart"	06/20 20:40	0:04	06/20 20:44
7	Pull bungie lanyard on beacon	06/20 20:44	0:10	06/20 20:54
8	Beacon out (hose clamp came off beacon holder - not useable)	06/20 20:54	0:06	06/20 21:00
9	Lanyard on board	06/20 21:00	0:08	06/20 21:08
10	Start transit	06/20 21:08	0:04	06/20 21:12
11	End transit, undock	06/20 21:12	0:48	06/20 22:00
12	BSP3 on bottom facing north	06/20 22:00	0:22	06/20 22:22
13	Rotated package to south	06/20 22:22	0:17	06/20 22:39
14	wait for cloud to clear	06/20 22:39	0:05	06/20 22:44
15	Remove left pin	06/20 22:44	0:02	06/20 22:46
16	Remove right pin	06/20 22:46	0:02	06/20 22:48
17	Reel placed on ROV basket, ROV up and away	06/20 22:48	0:06	06/20 22:54
18	Docked with TMS, ship heading 10 m S	06/20 22:54	0:05	06/20 22:59
19	Move ship 5 m at 190	06/20 22:59	0:11	06/20 23:10
20	Move ship 5 m at 205	06/20 23:10	0:04	06/20 23:14
21	Move ship 5 m at 205	06/20 23:14	0:06	06/20 23:20
22	Move ship 5 m at 205	06/20 23:20	0:04	06/20 23:24
23	Move ship 5 m at 205	06/20 23:24	0:02	06/20 23:26
24	Move ship 5 m at 205	06/20 23:26	0:03	06/20 23:29
25	Move ship 5 m at 215	06/20 23:29	0:09	06/20 23:38
26	Move ship 5 m at 215	06/20 23:38	0:01	06/20 23:39
27	Move ship 5 m at 215	06/20 23:39	0:05	06/20 23:44
28	Undock, 4 wraps left	06/20 23:44	0:08	06/20 23:52
29	Move ship 5 m at 215	06/20 23:52	0:03	06/20 23:55
30	On bottom, connector still in reel	06/20 23:55	0:04	06/20 23:59
31	Removing connector from reel	06/20 23:59	0:12	06/21 00:11
32	ODI connector free from reel	06/21 00:11	0:03	06/21 00:14
33	Transfer ODI to Mantis arm	06/21 00:14	0:02	06/21 00:16
34	Problem with yale grip eye on horn, breaks when on, grap with Mantis	06/21 00:16	0:47	06/21 01:03
35	Move ship to E	06/21 01:03	0:13	06/21 01:16
36	Move ship 10 m W	06/21 01:16	0:06	06/21 01:22
37	Move ship 5 m S	06/21 01:22	0:04	06/21 01:26
38	Move ship 5 m S, crossing cable between TF and Jbox	06/21 01:26	0:09	06/21 01:35

	39	At OBS E3, remove dummy from flying lead	06/21 01:35	0:03	06/21 01:38
	40	Plug in BSP3 ODI into E3	06/21 01:38	0:08	06/21 01:46
	41	Power on, test, works	06/21 01:46	0:03	06/21 01:49
	42	Turn to 080, wait for silt to clear	06/21 01:49	0:17	06/21 02:06
	43	Move ship at 20 m at 015, see crossing of TF-Jbox cable east of wuzzle??	06/21 02:06	0:04	06/21 02:10
	44	See cable heading 325	06/21 02:10	0:01	06/21 02:11
	45	Dock, head to SN1	06/21 02:11	0:00	06/21 02:11
12	**Move and connect SN1**				
	1	Ship stopped over SN1, 110 m from drop spot	06/21 02:11	0:54	06/21 03:05
	2	SN1 in view from TMS	06/21 03:05	0:09	06/21 03:14
	3	Undock	06/21 03:14	0:16	06/21 03:30
	4	stopping near SN1 for silt to clear	06/21 03:30	0:01	06/21 03:31
	5	Descent weights released from SN1	06/21 03:31	0:09	06/21 03:40
	6	ROV lift off to grab lifting line	06/21 03:40	0:01	06/21 03:41
	7	Eye on basket horn, pull up to TMS	06/21 03:41	0:01	06/21 03:42
	8	Docked	06/21 03:42	0:02	06/21 03:44
	9	Move ship 190 m at 125, pull up TMS so ROV altitude is 20 m (SN1 4 m below)	06/21 03:44	0:01	06/21 03:45
	10	< 100 m remaining, about half way	06/21 03:45	0:28	06/21 04:13
	11	Ship over site	06/21 04:13	0:05	06/21 04:18
	12	Move ship 20 m at 120	06/21 04:18	0:12	06/21 04:30
	13	Undock, SN1 on bottom just next to BSP3 reel and BSP in sight	06/21 04:30	0:12	06/21 04:42
	14	Removing beacon from top of SN1, beacon in basket (foam seems cracked in middle?)	06/21 04:42	0:20	06/21 05:02
	15	Move BSP3 reel out of way just east of SN1	06/21 05:02	0:02	06/21 05:04
	16	Remove hose ties/bungies	06/21 05:04	0:11	06/21 05:15
	17	Rotate SN1 left	06/21 05:15	0:23	06/21 05:38
	18	Unplug connector for OBS from J1	06/21 05:38	0:23	06/21 06:01
	19	Fly up over dust cloud to W of LIGHT4 and then to OBS, leaving space for moving LIGHT4	06/21 06:01	0:00	06/21 06:01
	20	At OBS, set connector on lower deck with dummy still in, move CTD mast out of way	06/21 06:01	1:35	06/21 07:36
	21	Remove environmental cover from E8	06/21 07:36	0:09	06/21 07:45
	22	Plug in SN1 connector to E8 - works	06/21 07:45	0:29	06/21 08:14
	23	Dock	06/21 08:14	0:12	06/21 08:26
13	**Ascent and Recovery - end of Dive 2 (LK-099)**				
	1	ROV ascends at 35 m/min	06/21 08:26	0:08	06/21 08:34

	2	Stop and test at 4000 m	06/21 08:34	0:00	06/21 08:34
	3	ROV ascends at 35 m/min	06/21 08:34	0:21	06/21 08:55
	4	Stop and test at 3000 m	06/21 08:55	0:00	06/21 08:55
	5	ROV ascends at 35 m/min	06/21 08:55	0:25	06/21 09:20
	6	Stop and test at 2000 m	06/21 09:20	0:00	06/21 09:20
	7	ROV ascends at 35 m/min	06/21 09:20	0:33	06/21 09:53
	8	Stop and test at 1000 m	06/21 09:53	0:00	06/21 09:53
	9	ROV ascends at 35 m/min	06/21 09:53	0:27	06/21 10:20
	10	Stop and test at 500 m	06/21 10:20	0:00	06/21 10:20
	10	ROV ascends at 30 m/min	06/21 10:20	0:17	06/21 10:37
	11	Recover ROV, on deck	06/21 10:37	0:28	06/21 11:05
14	**Prepare for next dive; ONR RAP work**				
	1	Prepare for next dive; ONR RAP work	06/21 11:05	14:10	06/22 01:15
15	**ROV Dive 3 (LK-100), Deploy ELEV, Recover BSP1**				
	1	Deploy ELEV 100 m E of BSP1 per ROV nav With USBL beacon, flasher, radio, acoustic release	06/22 01:15	0:00	06/22 01:15
	2	Move ship to ROV deployment position	06/22 01:15	0:26	06/22 01:41
	3	Deploy ROV	06/22 01:41	0:02	06/22 01:43
	4	Descend to 50 m and start ROV, switch winch stations	06/22 01:43	0:02	06/22 01:45
	5	continue to 500 m at 25 m/min	06/22 01:45	0:15	06/22 02:00
	6	at 372 m, 0.681 winch level wind chain broke; repair. ELEV on bottom at 0230 (63 m/min) near BSP3/SN1	06/22 02:00	3:04	06/22 05:04
	7	continue to 500 m at 25-30 m/min	06/22 05:04	0:11	06/22 05:15
	8	at 500 m testing	06/22 05:15	0:00	06/22 05:15
	9	continue to 1000 m at 30 m/min	06/22 05:15	0:15	06/22 05:30
	10	at 1000 m testing	06/22 05:30	0:00	06/22 05:30
	11	continue to 2000 m at 30 m/min	06/22 05:30	0:31	06/22 06:01
	12	At 2000 m testing	06/22 06:01	0:00	06/22 06:01
	13	Continue to 3000 m at 30 m/min	06/22 06:01	0:39	06/22 06:40
	14	At 3000 m testing	06/22 06:40	0:00	06/22 06:40
	15	Continue to 4000 m at 30 m/min	06/22 06:40	0:32	06/22 07:12
	16	At 4000 m testing	06/22 07:12	0:00	06/22 07:12
	17	Continue to 4650 m at 25 m/min	06/22 07:12	0:26	06/22 07:38
	18	At 4650 m, turn over to bottom work crew	06/22 07:38	0:04	06/22 07:42
	19	Undock at 4714 m, 19 m off bottom (4732 m) by ELEV	06/22 07:42	0:21	06/22 08:03
16	**BSP2 weights, OBS CTD mast, ELEV-BSP1**				

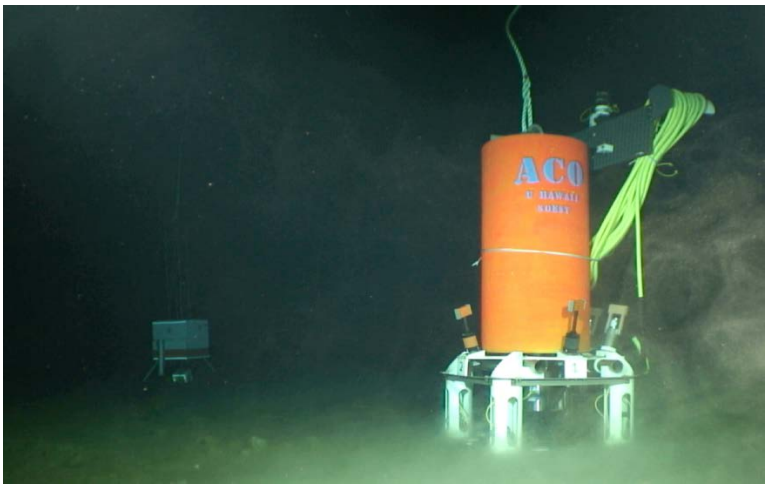
	1	Remove weights from ELEV. One 60 lb on horn, one in bakset	06/22 08:03	0:30	06/22 08:33
	2	Fly SW until all hose off reel and connector free (connector falls to bottom), undock, leave reel on bottom for later retrieval	06/22 08:33	0:22	06/22 08:55
	3	Move to BSP2 93 m at 193, BSP2 in sight	06/22 08:55	0:33	06/22 09:28
	4	On bottom next to BSP2	06/22 09:28	0:02	06/22 09:30
	5	Put weights with chain on BSP2	06/22 09:30	0:41	06/22 10:11
	6	Move to OBS to flip CTD back by E8, undock	06/22 10:11	0:31	06/22 10:42
	7	Flip CTD	06/22 10:42	0:04	06/22 10:46
	7	Dock	06/22 10:46	0:03	06/22 10:49
	8	Undock to reposition LIGHT4, dock	06/22 10:49	0:20	06/22 11:09
	9	Move to ELEV	06/22 11:09	0:38	06/22 11:47
	10	Undock to search	06/22 11:47	0:36	06/22 12:23
	11	Dock, search	06/22 12:23	0:08	06/22 12:31
	12	Undock	06/22 12:31	0:00	06/22 12:31
	13	Recover ELEV on horn, dock	06/22 12:31	0:08	06/22 12:39
	14	Move to E ?? of BSP1	06/22 12:39	0:55	06/22 13:34
	15	Set ELEV down, go to BSP1	06/22 13:34	0:00	06/22 13:34
	16	Lower CTD mast	06/22 13:34	0:08	06/22 13:42
	17	Lower acoustic modem mast	06/22 13:42	0:03	06/22 13:45
	18	Hook one caribiner on BSP1 bale	06/22 13:45	0:02	06/22 13:47
	19	Take other end to elevator. Too short. Add second length.	06/22 13:47	0:00	06/22 13:47
	20	Hook into float bridle (very difficult)	06/22 13:47	0:52	06/22 14:39
	21	Fix caribiner on BSP1 bale	06/22 14:39	0:06	06/22 14:45
	21	Pull pin on ELEV recover line float	06/22 14:45	0:04	06/22 14:49
17	**Ascent and Recovery - end of Dive 3 (LK-100)**				
	1	ROV ascends at 35 m/min	06/22 14:49	0:29	06/22 15:18
	2	Stop and test at 4000 m	06/22 15:18	0:00	06/22 15:18
	3	ROV ascends at 35 m/min	06/22 15:18	0:27	06/22 15:45
	4	Stop and test at 3000 m	06/22 15:45	0:00	06/22 15:45
	5	ROV ascends at 35 m/min	06/22 15:45	0:30	06/22 16:15
	6	Stop and test at 2000 m	06/22 16:15	0:00	06/22 16:15
	7	ROV ascends at 35 m/min	06/22 16:15	0:30	06/22 16:45
	8	Stop and test at 1000 m	06/22 16:45	0:00	06/22 16:45
	9	ROV ascends at 35 m/min	06/22 16:45	0:11	06/22 16:56
	10	Stop and test at 500 m - acoustially release ELEV+BSP1	06/22 16:56	0:03	06/22 16:59
	11	ROV ascends at 30 m/min	06/22 16:59	0:16	06/22 17:15

	12	Stop at 50 m and secure	06/22 17:15	0:03	06/22 17:18
	13	Recover ROV, on deck	06/22 17:18	0:07	06/22 17:25
	14	Buoy on surface	06/22 17:25	1:21	06/22 18:46
	15	Float secure on deck	06/22 18:46	1:10	06/22 19:56
	16	BSP1 secure on deck ??	06/22 19:56	0:15	06/22 20:11
18	**Transit to Haleiwa and Honolulu**				
	1	Transit	06/22 20:11	6:00	06/23 02:11
	2	At Haleiwa	06/23 02:11	2:00	06/23 04:11
	2	At Honolulu buoy	06/23 04:11	6:00	06/23 10:11
	3	Arrive	06/23 10:11	0:49	06/23 11:00
			06/18 10:00	**121:00**	**06/23 11:00**

	Start	**Duration**	**End**
Dive 1	06/19 04:38	18:48	06/19 23:26
Dive 2	06/20 12:25	22:40	06/21 11:05
Dive 3	06/22 01:41	15:44	06/22 17:25
		57:12	

Appendix B – Details of Operations

Aloha Cabled Observatory Maintenance Cruise
June 2018
Blue Eisen



Completed Operations

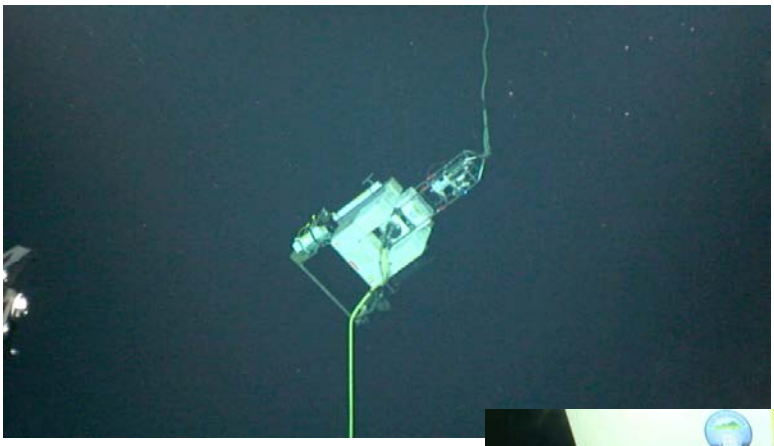
1. Attempted Recovery of BSP2

BSP2 is made of a Ti tower with a CTD, Fluorometer, Paro-Scientific Pressure sensor and a SIIM. Holding the base of the tower is a Ti frame with syntactic foam blocks and a drop weight. This design was intended to be self-recoverable, meaning that if the weights were released with a pull pin the entire package becomes buoyant. It has provisions for adding a RF beacon, flasher, and USBL prior to release by the ROV. Several months prior to the cruise, the pressure readings on both the paro-scientific and CTD dropped, corresponding to a depth change of about 38m. This was interpreted as the package came off the sea floor and was floating with the cable still attached and transmitting data. After about six weeks in this state, the pressure dropped again, indicating the package had move to about 50m off the sea floor. The PBOF hose connecting BSP2 to the OBS is 50m long.

Data from the pressure sensor indicated that the package was slightly lifted by the ROV during initial contact. At this point the data stream stopped. It is hypothesized that the wires in the connector at the SIIM broke. 50m of wire was hanging on the solder joints and any additional force was enough to break the connection. It is also possible that the connector at the OBS was stressed as the hose had a tight bend at this point.

BSP2 was moved away from the OBS and brought to the sea floor. The PBOF cable laid in almost a straight line between the two. Once on the sea floor, approximately 100 lb of shot bags were placed over the frame to hold it down. Once secure, the OBS end of the cable was inspected. On a later dive the port test tool was used to test the port that BSP2 was connected to. The port appears to be in good condition. On the third dive, 120 lb. of steel weight was added to

the frame with a combination of chain, nylon and polypro line. BSP2 was left on the sea floor with the connector hanging on the frame. A pin protecting dummy was used on the ODI flying lead.

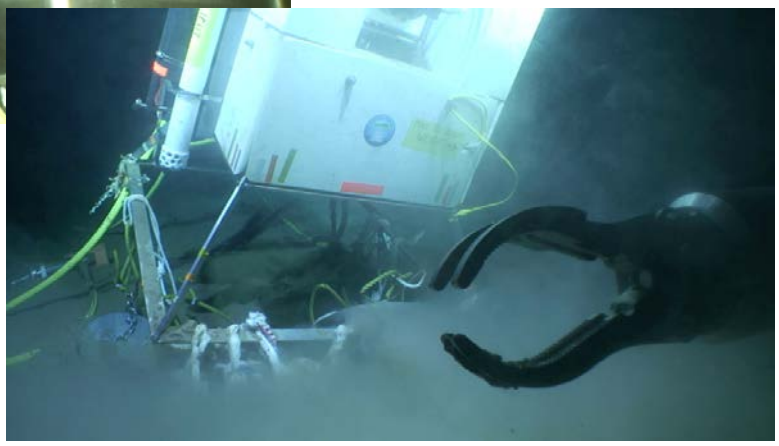


BSP2 as found, suspended 50m above the OBS

100 lb of shot bags added to BSP2 to hold it down temporarily.

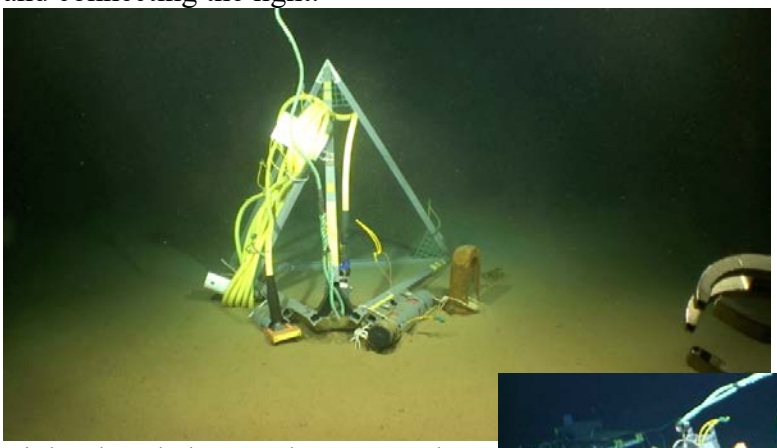
BSP2 PBOF cable in E1 with remaining bend after BSP2 was brought back to the sea floor.

Final configuration of BSP2. Steel weights and shot bags holding it down. Connector with dummy is hanging on the spool hook using Yale grip loop.

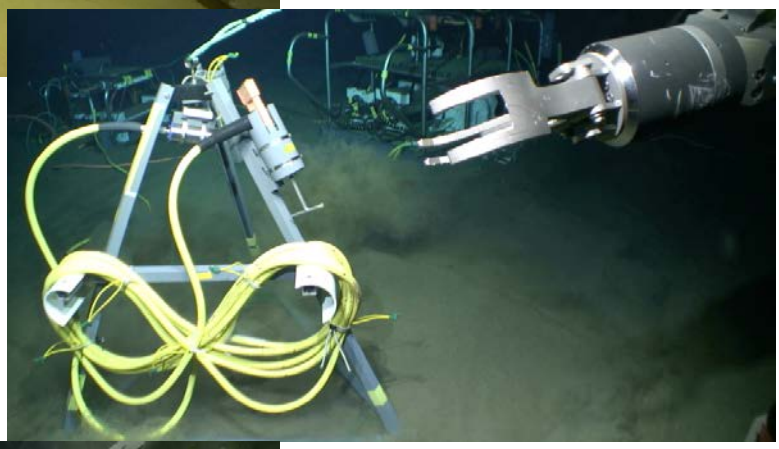


Connecting the Stand Alone Light

On a previous ACO cruise a tripod with a Cathex light had been deployed but time ran out before it could be connected. The light sat on the sea floor for two and a half years before we could get back to connect it. It was deployed with a USBL beacon which was recovered before moving and connecting the light.



Light tripod on its side where is sat between cruises.



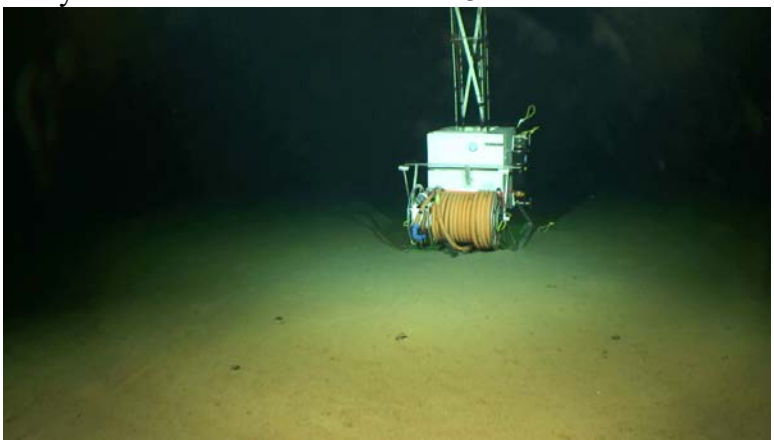
Light placed close to the OBS and camera before plugging it in.

Light was plugged into Port E2.

Light was moved to the right and rotated clockwise from the position shown for its final orientation.

2. Deployment of BSP3- icListen Hydrophone

BSP3 is a titanium frame and base similar to BSP2. The 50m cable was deployed on a spool attached to the frame. During descent a USBL beacon was used in a holster to track the package and locate on the sea floor. The spool was removed from the frame and hung on the ROV basket to lay the PBOF cable between BSP3 and the OBS.

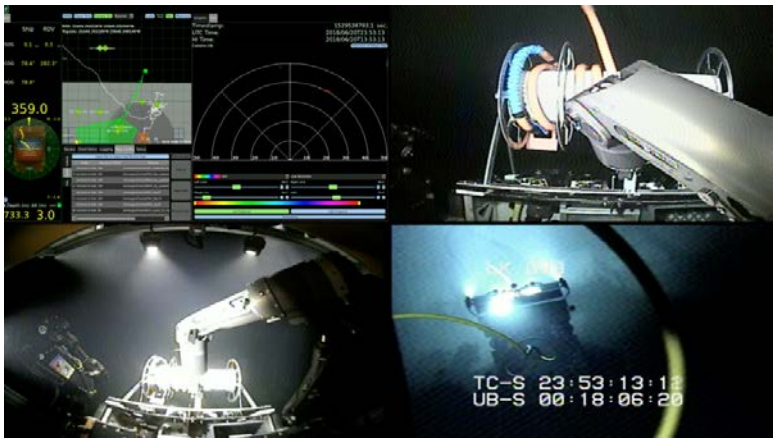


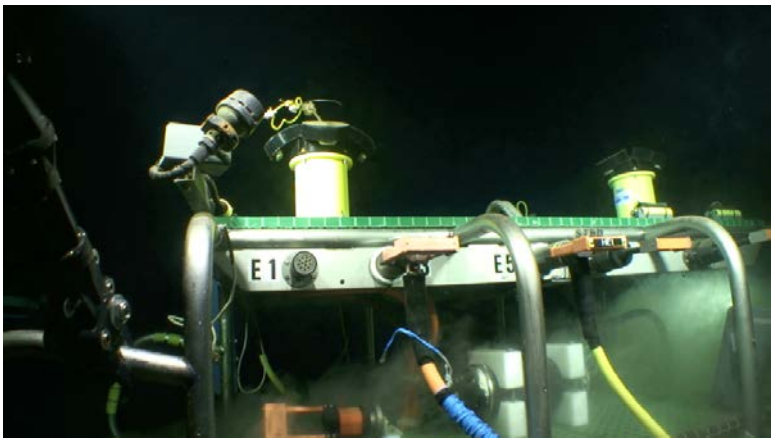
BSP3 on sea floor as first found after deployment.

When the USBL was removed from the holster the hose clamp came loose. The holster is loose and is not usable for recovery.

The hose reel mount on the basket worked well. It was quick to connect, and the hose spooled off cleanly. The ROV was backed up to the OBS, it will be better to fly forward to see where to land and have the hose trail under the ROV.

With several wraps remaining on the reel the ROV undocked from the TMS and landed. The last few wraps were then removed from the reel on the sea floor.

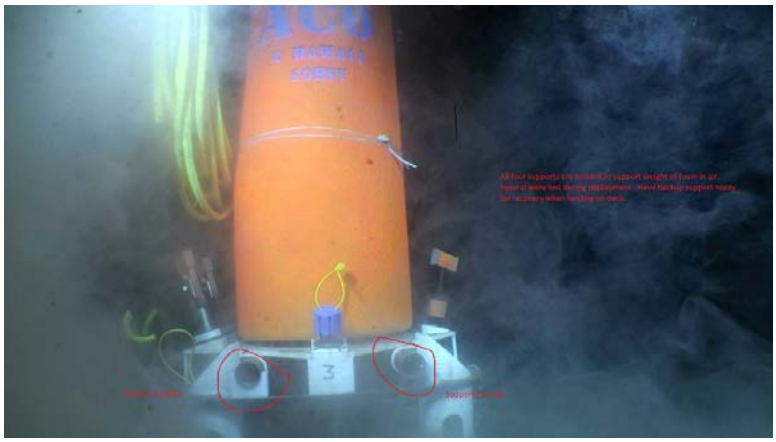




BSP 3 was plugged into E3 on the OBS. Broken Yale grip loop can be seen.

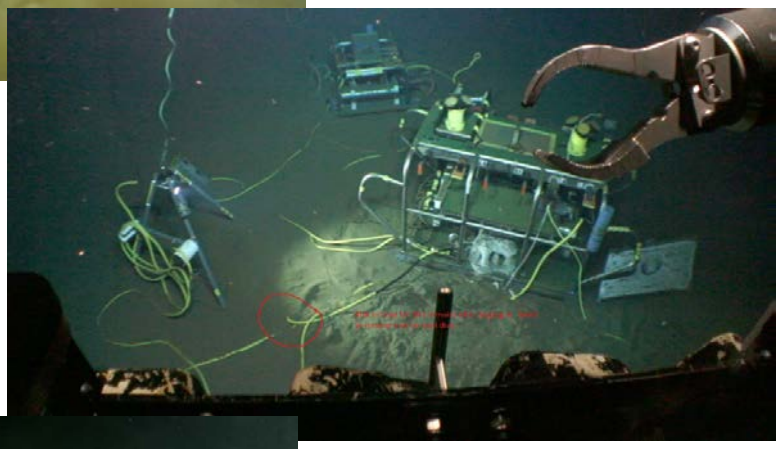
3. Deployment of SN1

SN1 is made from most of the old AMM. The electronics, pressure case and PBOF cables are new but the Frame and flotation was repurposed. The new pressure case is much smaller and lighter than the AMM so weight had to be added to the base in order to make it stable on the sea floor. Eight 20 lb. steel plates were bolted to the FRP grating using titanium bolts and Delrin plate as washers. Each plate also has a zinc anode on it. Additional lead weight was used in each of the pockets. The 50 m PBOF hose has two ODI flying leads so it can be disconnected at both ends. The hose was deployed on "bull horns" rather than a spool.



Delrin spacers in the frame came loose during deployment. Although this configuration had been used before, with the added weight on the base several were lost. These spacers are only needed to support the weight of the foam in air. We will need to have some ready when it is recovered and placed on deck.

When the PBOf hose was taken off the “bull horns” it did not lay as well as with the spool. Several twists remain in the hose. One is a tight kink close to the OBS. This needs to be removed on the next dive.

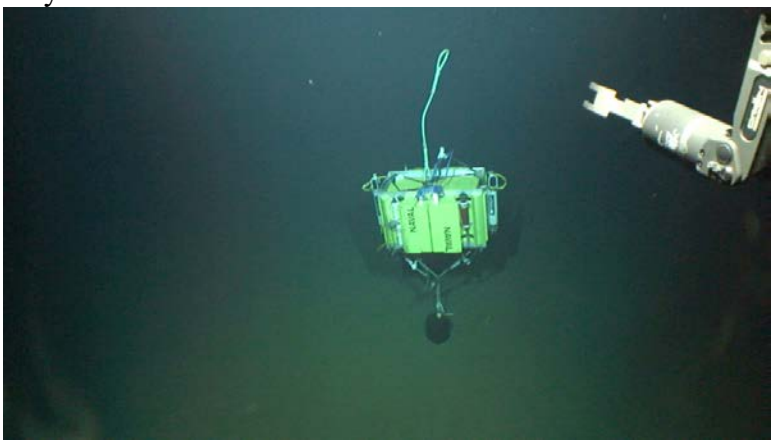


Another view of the kink in the SN1 hose at the OBS.

SN1 was plugged into port E8 of the OBS.

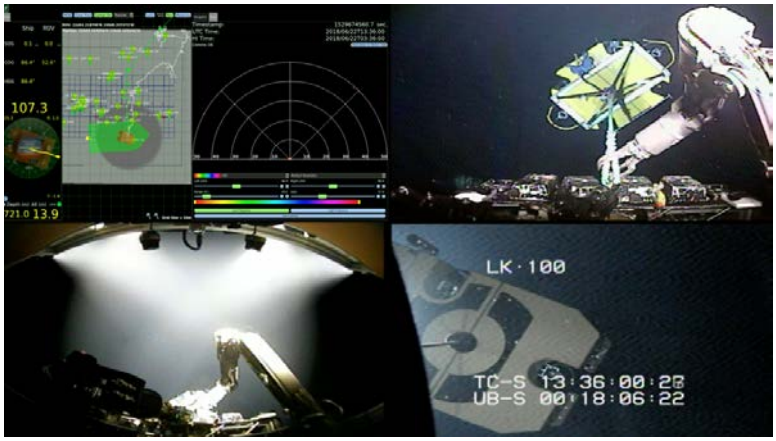
4. Recovery of BSP1

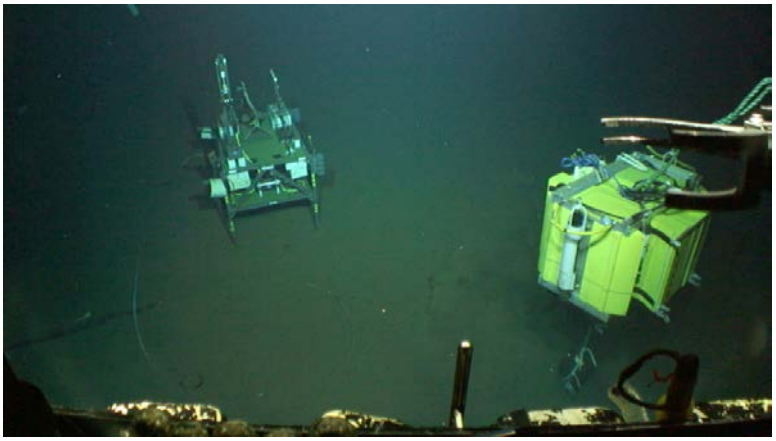
Four individual packages needed to be recovered for repair (including now BSP2). Due to the complexity of a multiple package lift and limited time it was prioritized that BSP1 would be first. Then as time permitted we would add others to the elevator. It turned out that BSP1 was the only one to be recovered.



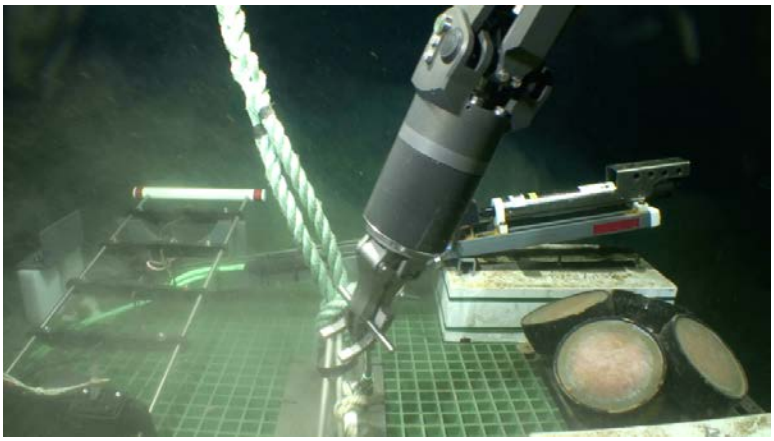
A large syntactic foam elevator was deployed. The elevator has lift capacity of almost 500 lb. A 60m line was held in a canaster which could be laid on the sea floor. The line has six loops to which various packages could be attached. The elevator has RF beacon, USBL tracking and a flasher. The drop weight is released by either of two independent acoustic releases.

The elevator was moved to the area of BSP1. As with all packages, the lift line was placed on the "Rhino Horn" and the ROV docked in the TMS. The ship then moves to the new location.



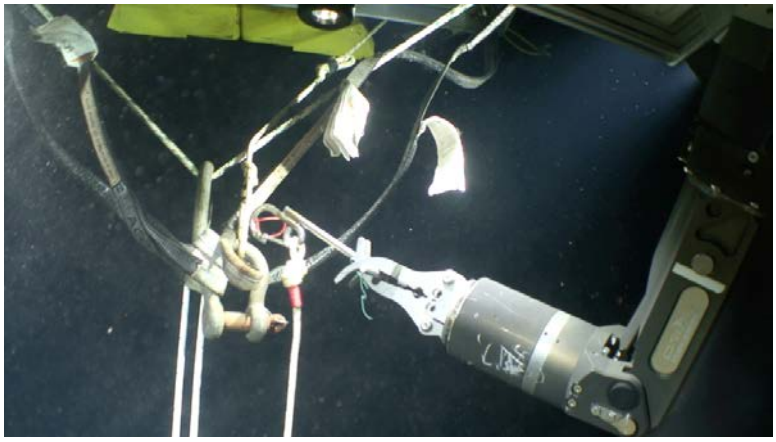


The elevator placed close to BSP1. The initial intention was to connect the end of the 60m line to BSP1 then move the elevator away as the line played out. Due to limited time, BSP1 was connected directly to the elevator.



A line, with two carabiners with T-handles, was clipped onto the lift point of BSP1.

The other end of the line was clipped into the harness of the elevator, bypassing the 60 m lift line.



Post Cruise Thoughts and Review Items

1. Deployment and Descent Weights
    a. Chain vs. Line

        Small, long link chain provides a secure and easily removable link between depressor weight and package. It is only one time use so it does not need to be corrosion resistant. A cotter pin used as a pull pin works well and has not yet got hung up. The chain almost disappears in the sediment. Nylon line sinks but it has too much potential to get caught in thrusters if it comes off sea floor.

    b. Descent Rate

        Intended descent rate is about 60m/min. In practice, it appears that size of depressor weight is more of a factor than package shape. BSP3 had the Duennebier plaque which weighed about 50 lb in water and descended at 50-60 m/min. SN1 had 120 lb of 20 lb plates and descended at over 80m/min. In general, one 80 lb spelter

socket on 40 ft of chain should be a good general starting point for a 60lb (wet on bottom) package.

c. Disconnecting from Package

A cotter pin used as a pull pin works well and has not yet got hung up on either chain or bungee.

d. Accumulating "junk"

Unused equipment is starting to accumulate on sea floor. It is getting more important to get items into one area otherwise they cause problems/delays in operations. We now have various weights spread around and they cause hoses to hang when being stretched or pulled into position. There are now two spools on the sea floor which are highly visible and cause confusion when trying to identify objects from a distance.

2. Packages

a. Size/Height for manipulator work

With Lu'ukai being smaller than other ROVs the placement of items needs to be closer to the floor. It could be possible to build in a "bench" for the ROV to rest on if a package needs to be large

b. Number of instruments, failure points

The give and take on the number of instruments on a package needs to be considered. A package with many instruments has a higher likelyhood of having one or more failures. If one or two instruments fail, the entire package needs to be recovered and all other instruments are then taken out of service. However, if only a few instruments are on a package a failure is less likely and recovery of the package removes fewer working instruments. The smaller number of instruments per package requires more ports to be used and more individual operations.

c. Materials

With the recovery of BSP1, it is clear that stainless steel is not an acceptable material for long term deployment. Part of the frame and many fasteners had failure points. Titanium, polymers and FRP grating continue to show good structural integrity and corrosion resistance after multiple year deployments. Steel drop weights are also showing corrosion at greater rates than expected. If a package is buoyant and needs weight for anchoring, lead which is 100% isolated from other metals should be considered.

3. Moving packages

a. Total size/mass

It has been shown that Lu'ukai can lift 120 lb with 50% thrust. This condition is achievable but with extremely limited maneuverability and excessive pitch angles. Packages with a bottom wet weight of 60 lb are manageable for the ROV and stable on bottom. This should be a target weight for most packages deployed or recovered by Lu'ukai. Total mass is another important consideration. When the ROV is docked in the TMS the heave of the ship is translated to the package through the TMS frame, chimney and rhino horn. The forces required to accelerate a large mass, regardless of the wet weight can be excessive and cause damage to the ROV. On this cruise we had several package masses to experiment with. BSP3 had a wet weight of about 60 lb. and a mass of about 500lb. While docked, the basket had small flex and the strain seemed reasonable. SN1 had a bottom weight of about 80 lb. and a mass of 800 lb.

Flex in the basket at the rhino horn was much more pronounced despite relatively calm surface conditions. The Elevator had a bottom weight of about 80 lb. also but a mass of about 1400 lb. Still with fairly calm surface conditions, flex in the basket was Sevier and with large hydrodynamic drag the flotation came up to level with the basket before dropping again.

For deployment/recovery with Lu‘ukai it is recommended that total package mass be kept below 500-700 lb with a bottom weight of 60-80 lb. This includes the total elevator mass.

b. Lift Lines

1” or larger blue poly with eye splice on both ends and total length of 6’ works well for lifting all packages. This size line is too large to get into the thrusters and hooks to the rhino horn easily. The package hangs clear of the skids but not to far below the ROV. Total height above the sea floor is minimized so transit altitude does not need to be excessive in order to clear packages below.

c. Time to move ship

The time required to move the ship from one location to another is significant and requires patience from all parties involved. This time is largely affected by the distance a package needs to be moved. Therefore, selection of drop location is important

d. Deployment Location

On the 2018 cruise three separate packages were deployed on different days and times. All three had approximately 200 m (toward the north west) horizontal displacement from drop location to final landing point. This consistent displacement was seen despite different bottom and surface currents at time of deployment. If drop locations had been selected based on this knowledge hours would have been saved by reducing transit times. This does not imply that the same horizontal displacement will always occur but may be consistent from one day to the next.

Deployment location should also consider the accumulation of descent weights. The 80 lb. descent weight is abandoned at the landing location and can cause a nucence in the future if it is too close to the observatory or between the observatory and other equipment.

4. PBOF Hoses and ODI Connectors

a. Plugging/Unplugging

The bulkhead connectors on the OBS are all about two meters off the seafloor. This creates difficulty for Lu‘ukai as the manipulators can not reach with the skids on the ground. Using the Sea Mantis to hold on to the frame while the Orion operates the connector works but is a difficult operation and takes a lot of time. It has been suggested to make a “bench” for Lu‘ukai to rest on (basket partially extended) which would be placed by the OBS.

b. Pin Protecting Dummies

With the geometry of the manipulators it is not practicle to place a pin protecting dummy on the ODI connectors using the T-handle method. It would be advantageous to place extra dummies on the top front of the basket so that the ODI connector could be pressed onto the dummy, using the basket for resistance. This could provide an

easy place to store the dummies and make using them easier. In addition, the T could be replaced with a paddle handle. The only difference would be a plate (soft material like ODI connectors/environmental covers) across the top instead of a round bar. This would give a much better grip with the arms and could even make some kind of basket clip for them easier to use. This might also be extended to the carabiners.

c. Spools

The spool design has shown to work efficiently. It attaches to the basket quickly and stays in place with minimal manipulator intervention. The cable lays out in a straight line without any kinks or hockles in the hose. The down side is that we have the spool sitting close to the OBS and can be a nuisance. It is important that we move the spools to a gathering area or recover them during operations. A spool that is recovered within a few days can likely be used again. However, if it is left on the sea floor for any extended amount of time, is unlikely that it would be usable again.

d. Yale grip

A Yale Grip type loop on both ends of a hose just short of the connector is a simple and convenient way to connect the hose to the rhino horn if the hose needs to be pulled on. Using small line allows the loop to get pinched and makes it hard to get on the horn. A thimble or plastic spiral wrap in the loop would simplify the hooking to the horn and give some added protection to the line.

5. Recovery

Two recovery methods have been tried now. Both have advantages and disadvantages. Using the elevator provides the ability to have redundant acoustic releases, solid beacon connections and a highly visible marker on the surface. The ROV can be well on its way up before the package is released. The disadvantage to the elevator is that it takes time for deployment and moving it to the package to be recovered. In order for the elevator to have sufficient buoyancy for large packages it must have a large mass (see package size discussion above).

The self-recoverable packages require the ROV to be on the bottom when released and the ROV generally needs to be recovered before the package. The package will generally ascend faster than the ROV and must sit on the surface until the ROV is recovered unless a small boat is used. This is due to the limited maneuverability of the ship with the ROV in the water. The advantage is that no time is used in setting the elevator. A failure of the drop weight has shown to be catastrophic.

a. Elevator

i. Total size, mass, lift

The size of the elevator should be representative of the package it will recover. This limits waist for the drop weights and limits unneeded stress on the ROV when moving the elevator into position.

ii. Modular

A Modular elevator system would allow adjustment based on need as dictated by the size/weight of the package to be recovered. The current elevator is not modular and would need modifications.

iii. Number of packages per lift

It was intended on this cruise to connect multiple packages to one elevator lift. After exacting the lift with only one package, it became abundantly clear that only one package should be attempted at a time. The complexity of

rigging on the sea floor is too much for efficient ROV operation and the risk at the surface of loosing a package is greatly increased beyond what is reasonable.

iv. Size of package

The physical dimension of the package is limited by the reach of the crane to get it on board. When the last bite is taken on the lift line to the crane there must be enough room to get the remaining lift line and package on deck. We have about 60 feet from deck to the crane at full extension. Small loops and small rigging can be passed through the block on the crane.

v. Chafe Protection

The t-handle on the carabiner chafes on the line when there is any tension. It is critical to protect all lines from any possible chafing as the elevator may be on the surface for an extended amount of time especially in rough conditions.

vi. Line Sizing

Safe working load on the lift line should be at a minimum 10x the total mass of the package

b. Self-Recoverable

i. Drop Weights

1. Material

It appears that steel drop weight is corroding faster than expected. We are now thinking lead to be the preferred weight. We don't want to leave too much lead on the sea floor.

Another possibility would be in which the weights are fastened to the FRP grating with the entire grating jettisoned to recover the package (like BSP3). Regular concrete could be poured over the FRP frame (in a form, of course) to provide the needed weight. The FRP would take the place of steel fittings that would reinforce the concrete and provide an attachment point. The amount of concrete could easily be adjusted for the required weight and even made onboard, if necessary. And, of course, concrete is non metallic and fairly environmentally friendly.

2. Galvanic isolation

It is critical that all metals are completely isolated from the attachment hardware and the rest of the package. All metals should be protected by sacrificial anodes.

3. Release mechanism

Can the ROV get clear? Can it pre-release?

4. Expected life span

This will depend on the material and isolation/anode configuration. Error on the shorter life span.

ii. Syntactic foam and Total mass/size

See discussion above about mass. By making a package self-recoverable more foam is needed, therefor more weight.

6. ROV Basket Configuration
    a. Dedicated, reinforced basket.
    b. Easy basket change out.
    c. Latch to hold lines on rhino horn, fail open.
    d. Permanente Spool/Equipment hangers
    e. Pin Protecting dummies easy access
    f. Standard Ballast
    g. ROV Tools
        i. Carabiners
        ii. Knifes
        iii. Tools

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