**Cruise Report for R/V *Kilo Moana* KM-15-16:**
**ALOHA Cabled Observatory Service**
**16-21 September 2015**

9 September 2016

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## Summary

The purpose of this NSF-funded cruise on the R/V *Kilo Moana* was to service the infrastructure and instrumentation on the ALOHA Cabled Observatory (ACO). ACO is the deepest operating cabled observatory on the planet, at 4728 m water depth. The highest priority science mission objective was achieved, to install and connect basic sensor package 2 (BSP2, with a nano-resolution pressure sensor, fluorometer/turbidity sensor and $CTDO_2$). Secondary objectives – to connect LIGHT4 (to enable CAM1) and to retrieve three packages (BSP1, CAM2, and LIGHT1) – were not achieved. BSP2 data is flowing to the web page and the ftp site and appears good. A major accomplishment was the demonstration that the UH ROV *Lu'ukai* can do this work, although significant steps remain before it is a fully operational system.

The cruise was 5 days long, from 1030 Wednesday 16 September – 0800 Monday 21 September 2014. An ROV test dive was conducted immediately after leaving Honolulu. Then upon arrival at Station ALOHA 100 km north of Oahu, multiple dives were made to debug ROV problems. On Dive 7, the BSP2 was found after freefalling to the bottom. On Dive 8, the BSP2 was moved and connected; at that point loss of ROV hydraulic pressure required recovery after being on the bottom 5.5 hours. The little remaining time on station was used to recover errant Seaglider SG146 for D. Karl. Weather was good, starting at 15 kt winds from the east and 5 ft seas and ending at 20-25 kt winds and 10 ft seas. With the addition of 1280 lb of lead on the ROV tether management system (TMS) and with the 0.681 wire running through the new slack tensioner unit, the ROV descended at 40 m/min and ascended at 45 m/min with no problem.

## Detail

The basic tasks and timeline are summarized in Table 1 and are largely self-explanatory; the detailed timeline is in Appendix C. The line diagram map shows the locations of the various components (Figure 1) and the block/wiring diagram for the seafloor equipment is given in Appendix A. Figures 2 – 7 show the components deployed and a picture of the science and ROV party on the *Kilo Moana*. Figure 8 shows the elevator that was not used; it was intended to use it to recover CAM2, BSP1 and LIGHT1. The list of participants is given in Appendix B.

*Table 1 Summary cruise tasks and times (UTC; local HST time = UTC – 10)*

| | Task | Start | hh:mm | End |
|---|---|---|---|---|
| 1 | Transit to Station ALOHA and ACO | 09/16 20:30 | 2:20 | 09/16 22:50 |
| 2 | Dive 1 (LK-048) | 09/16 22:50 | 1:55 | 09/17 00:45 |
| 3 | Transit to Station Aloha | 09/17 00:45 | 12:45 | 09/17 13:30 |
| 4 | ROV Dive 2 (LK-049) | 09/17 13:30 | 4:17 | 09/17 17:47 |

| | | | | |
|---|---|---|---|---|
| 5 | Repair ROV | 09/17 17:47 | 15:17 | 09/18 09:04 |
| 6 | ROV Dive 3 (LK-050) | 09/18 09:04 | 4:38 | 09/18 13:42 |
| 7 | Repair ROV | 09/18 13:42 | 5:33 | 09/18 19:15 |
| 8 | ROV Dive 4 (LK-051) | 09/18 19:15 | 6:36 | 09/19 01:51 |
| 9 | Repair ROV | 09/19 01:51 | 5:29 | 09/19 07:20 |
| 10 | ROV Dive 5 (LK-052) | 09/19 07:20 | 7:15 | 09/19 14:35 |
| 11 | Repair ROV | 09/19 14:35 | 8:28 | 09/19 23:03 |
| 12 | ROV Dive 6 (LK-053) | 09/19 23:03 | 1:24 | 09/20 00:27 |
| 13 | Repair ROV | 09/20 00:27 | 2:15 | 09/20 02:42 |
| 14 | ROV Dive 7 (LK-054), and BSP2 | 09/20 02:42 | 3:51 | 09/20 06:33 |
| 15 | Prepare BSP2 and remove LIGHT1 connector | 09/20 06:33 | 5:45 | 09/20 12:18 |
| 16 | Repair ROV | 09/20 12:18 | 5:15 | 09/20 17:33 |
| 17 | ROV Dive 8 (LK-055), LIGHT4 | 09/20 17:33 | 3:03 | 09/20 20:36 |
| 18 | Connect BSP2 | 09/20 20:36 | 4:21 | 09/21 00:57 |
| 19 | Go to LIGHT4 | 09/21 00:57 | 0:54 | 09/21 01:51 |
| 20 | Ascent and Recovery, end ROV Dive 8 (LK-055) | 09/21 01:51 | 2:07 | 09/21 03:58 |
| 21 | Recover Seaglider | 09/21 03:58 | 3:02 | 09/21 07:00 |
| 22 | Transit to Honolulu | 09/21 07:00 | 11:00 | 09/21 18:00 |

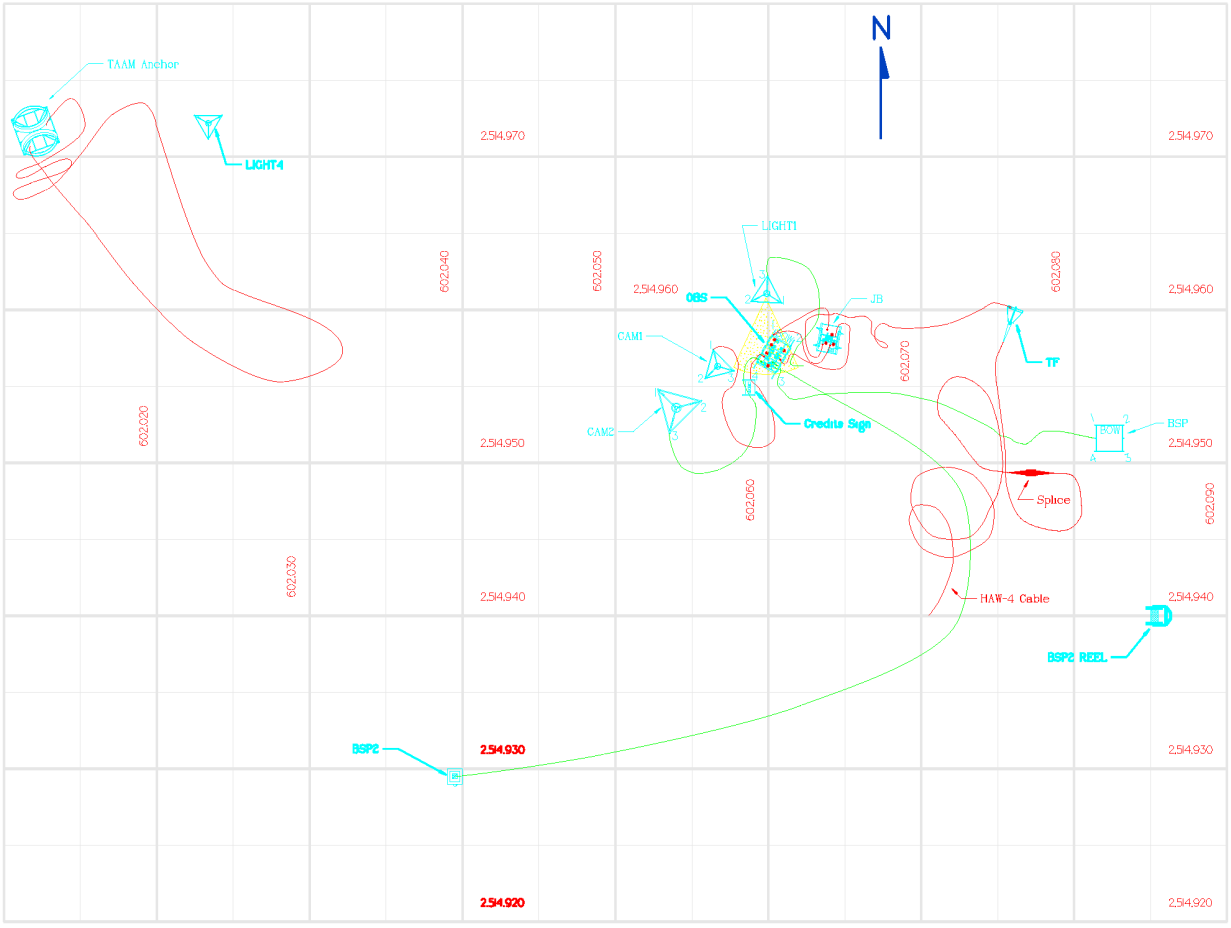


*Figure 1 ACO bottom configuration at the end of the cruise, 21 September 2015.*

*Figure 2 ROV Lu'ukai on deck.*

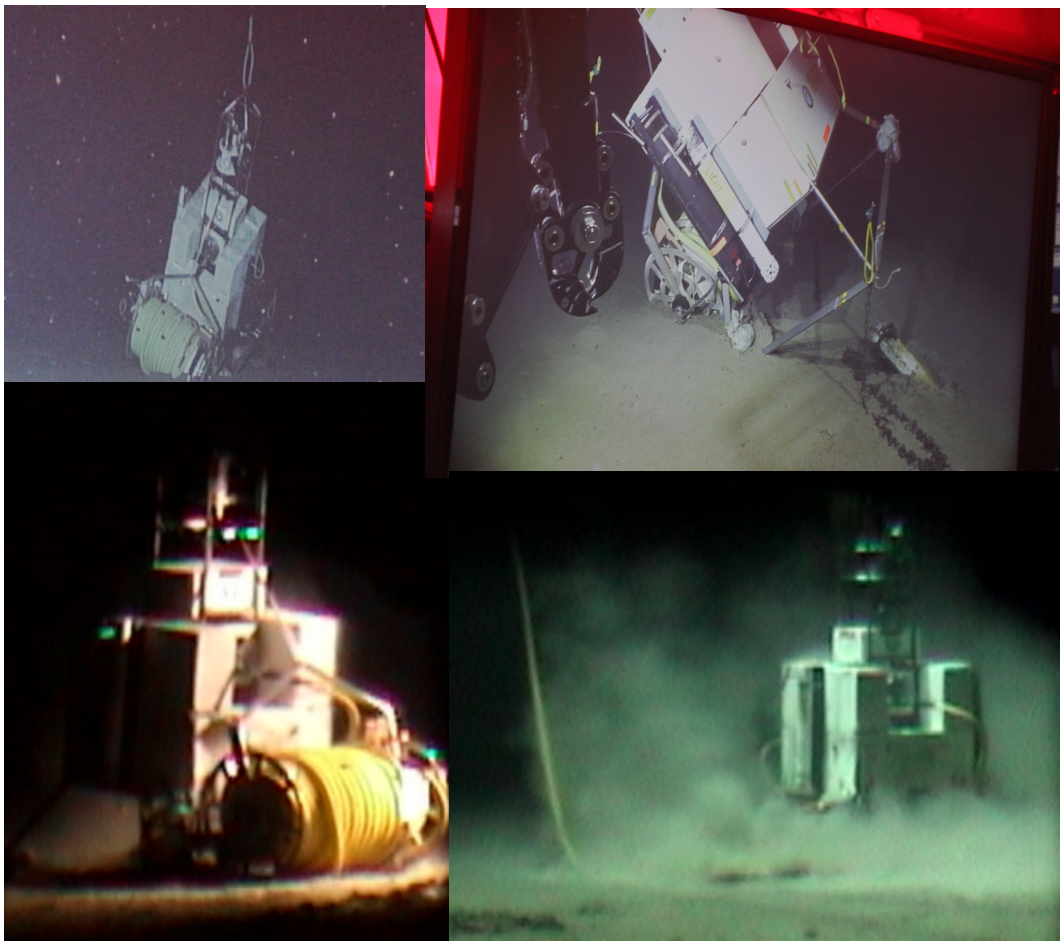

*Figure 3 ACO Basic Sensor Package2 (BSP2) as viewed by ROV Lu'ukai and CAM1. In the bottom right image, Lu'ukai is above left unspooling the yellow connecting hose.*

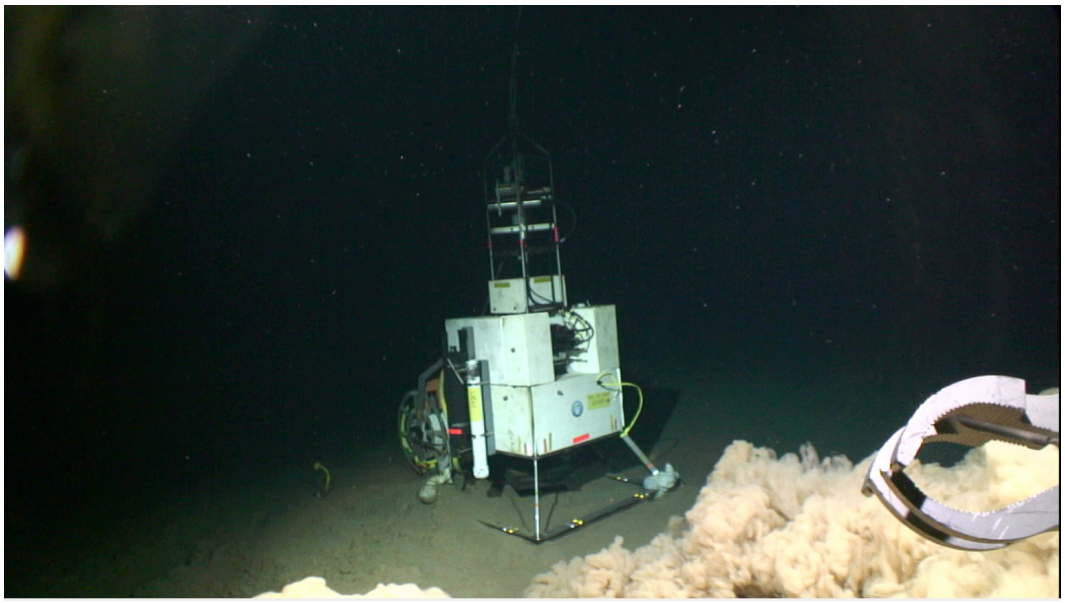

*Figure 4 BSP2 as viewed by Lu'ukai after it has been leveled with weight bags (right corner of frame).*

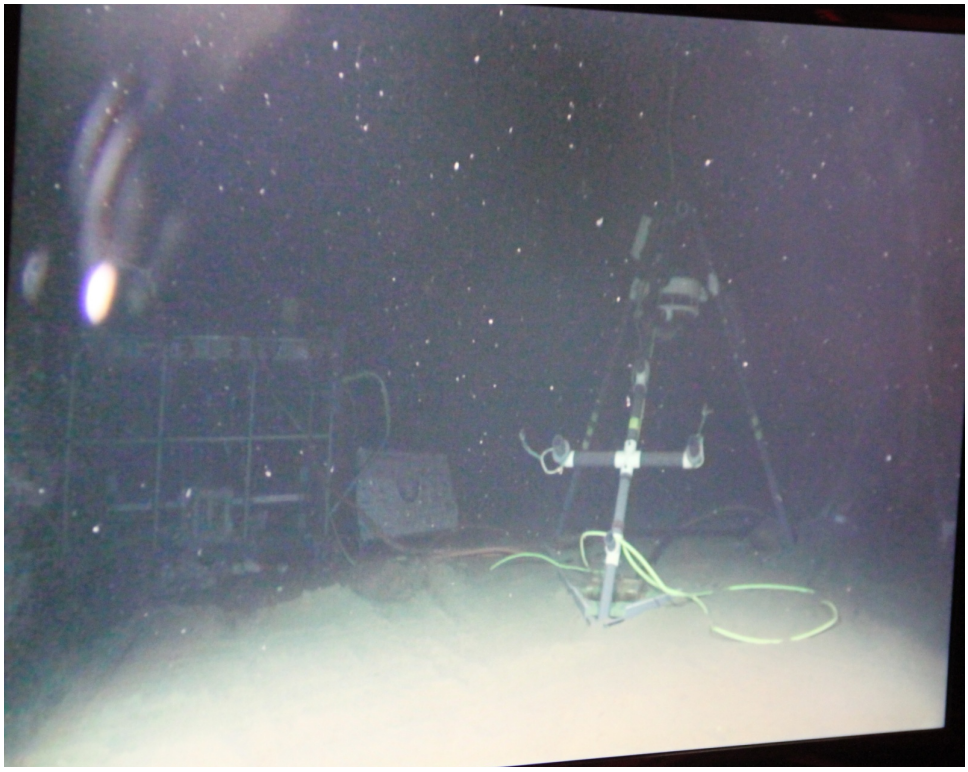

*Figure 5 From Lu'ukai, the observatory, banner acknowledging organizations who have contributed to ACO, and CAM1.*

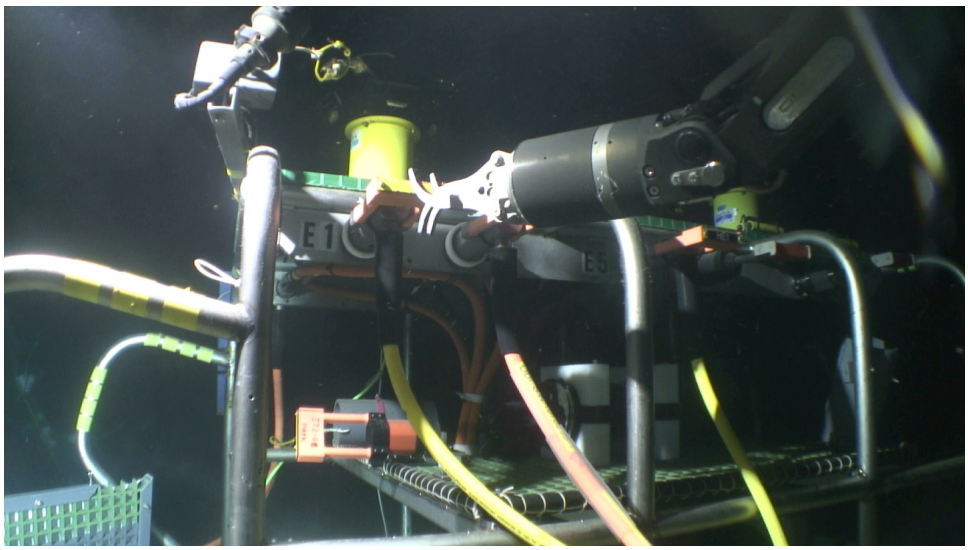


*Figure 6 Lu'ukai connecting BSP2 to Port E1 on the observatory.*

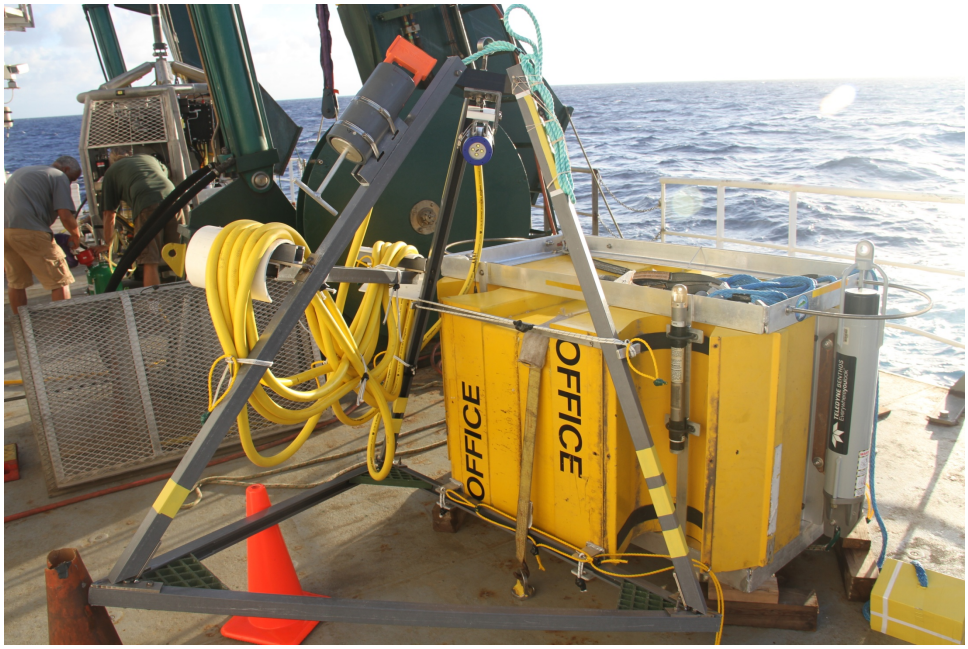


*Figure 7 ELEVATOR set up with LIGHT 4 for deployment. Later, LIGHT4 was dropped by itself.*

*Figure 8 LIGHT4 on its side at 0144 UTC on 21 September UTC*


*Figure 9 The science and Lu'ukai party*

**Acknowledgments**

We thank the captain and crew of the R/V *Kilo Moana* for their support during the cruise. The *Lu'ukai* team was excellent, very professionally and efficiently executing the necessary tasks with good cheer even when at times operations were frustrating and stressful, to say the least.

The cruise and shore party participants are given in Appendix B. This work represents the effort of a large team – everyone was essential and contributed to the success. Blue Eisen, project engineer, designed much of the new equipment. Grant Blackinton, project engineer during the ACO installation phase, assisted in the cruise planning and shared the direction of the *Lu'ukai* operations.

This work is supported by the National Science Foundation, grants OCE 1239637 and 1539244.

# Appendix A – ACO Diagram

The following diagram shows components of ACO in a schematic form, naming frames, connectors and cables, pressure cases and endcaps, sensors, etc.

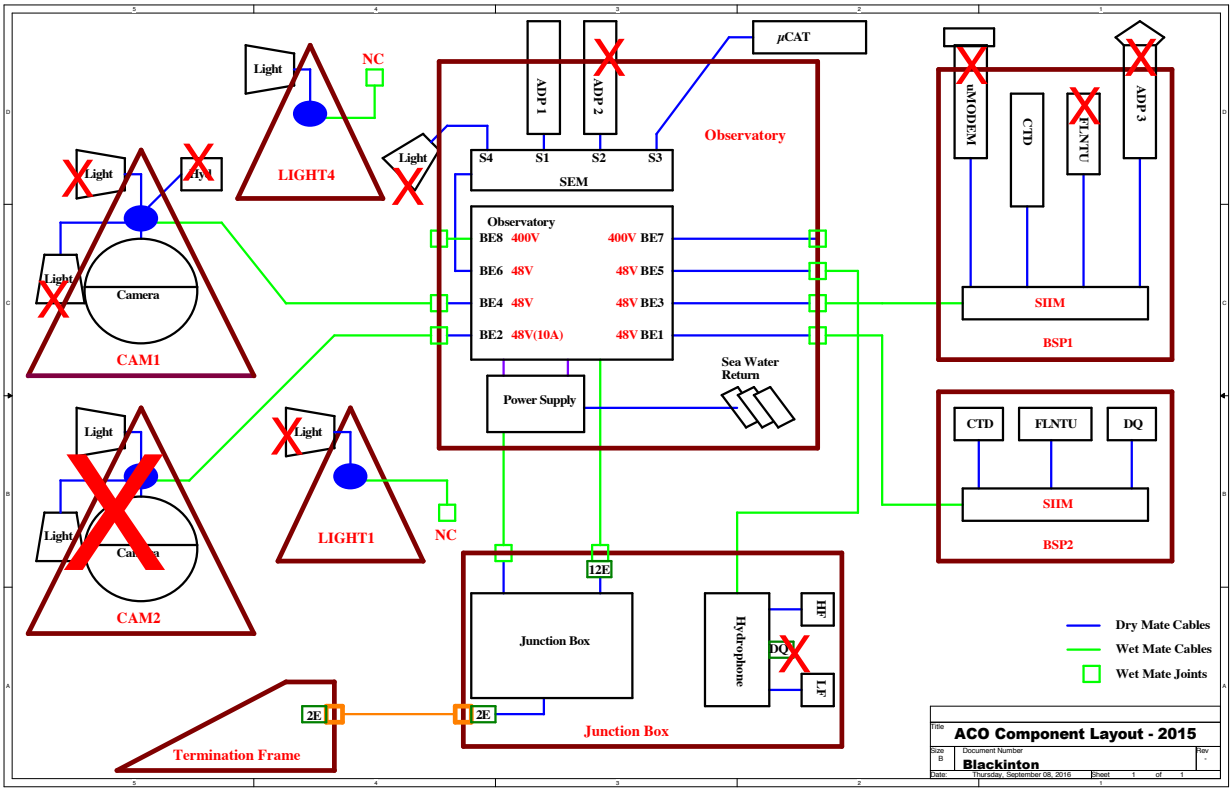


*Figure A-1 ACO bottom interconnection diagram – 21 September 2015*

# Appendix B – Cruise and Shore Party Participants

| | Name | Position | Email | Phone |
|---|---|---|---|---|
| | **Cruise Participants** | | | |
| | **ACO** | | | |
| 1 | Bruce Howe | Chief Scientist | bhowe@hawaii.edu | Cell: 808-469-0553<br>Off: 808-956-0466<br>Hm: 808-888-0665<br>Iridium:<br>011-8816-22426745 |
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| 3 | Grant Blackinton | Engineer | grant@blackinton.org | Cell: 206-579-7738 |
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| 5 | Vincent Varamo | Student | varamo@hawaii.edu | Cell: 704-651-5998 |
| 6 | Burton Sadler | Student | bsadler94@gmail.com | Cell: 650-703-4924 |
| | | | | |
| | **ROV *Lu'ukai*** | | | |
| 7 | Max Cremer | Pilot | mcremer@hawaii.edu | Cell: 808-222-9588 |
| 8 | Terry Kerby | Dive Supervisor<br>Manip ops | tkerby@hawaii.edu, | Cell: 808-394-7056 |
| 9 | Dan Greeson | Pilot | greeson@hawaii.edu | Off: 808-842-5799 |
| 10 | Scott Reed | Manip Ops | scott.reed@gmail.com | Cell: 808-304-2156 |
| 11 | Steve Tottori | Navigator/Tech | snt@soest.hawaii.edu, | 508-289-2273 |
| 12 | John Smith | Navigator | jrsmith@hawaii.edu | Off: 808-956-9669 |
| 13 | Steve Price | Navigator/<br>Manip ops | stevenpr@hawaii.edu | Cell: 808-888-6248 |
| 14 | Scott Ferguson | Deck/Engineer/Navigator | jscottf@hawaii.edu | Cell: 808-349-2750<br>Off: 808-832-3081 |
| 15 | Jeff Koch | Manip Ops | jkoch4@hawaii.edu | Cell: 808-221-8774 |
| 16 | Ian Griffith | DOER Engineer | ian@doermarine.com | |
| 17 | Tony Lawson | DOER Engineer | tony@doermarine.com | |
| | | | | |
| | **OTG** | | | |
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| | Scott Ferguson | Director, Marine Technical Services | jscottf@hawaii.edu | Cell: 808-349-2750<br>Off: 808-832-3081 |
| | Jeff Koch | Manip Ops | jkoch4@hawaii.edu | Cell: 808-221-8774 |
| 18 | Sonia Brugger | | | |
| | | | | |
| | **UH/ACO** | | | |
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| | Fred Duennebier | Scientist | fred@soest.hawaii.edu | Cell: 808-398-4628<br>Hm: 808-373-3669 |
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| | Brian Chee | Network Specialist | chee@hawaii.edu | Off: 808-956-5797<br>Cell: 808-372-7426 |
| | Jim Jolly | Engineer | jjolly@hawaii.edu | Lab: 808-956-2488<br>Cell: 808-392-4784 |
| | Jim Babinec | Technician | babinec@hawaii.edu | Lab: 808-956-2876 |
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| | Jon Imai | Machinist | jimai@hawaii.edu | |
| | Karynne Morgan | Project Asst | karynnem@hawaii.edu | 808-956-6036 |
| | Kellie Terada | Project Asst | kterada@hawaii.edu | 808-956-4101 |

# Appendix C – Detailed cruise timeline

| | | *** UTC *** | 09/16 20:30 | | 09/21 18:00 |
|---|---|---|---|---|---|
| | | **Task** | **Start** | **hh:mm** | **End** |
| **1** | **Transit to Site 1, 430 m** | | | | |
| | 1 | Transit | 09/16 20:30 | 2:00 | 09/16 22:30 |
| | 2 | Load ROV basket: weighs, knife, brushes and chisels for cleaning sea water return (SWR), 1 ODI Environmental Cover (EC), snap-hook-lines, 1 ODI pin-protecting dummy with T-handle | 09/16 22:30 | 0:00 | 09/16 22:30 |
| | 3 | Establish ship in DP mode at Site 1, Connector Test Frame, Bottom depth 431 m. | 09/16 22:30 | 0:20 | 09/16 22:50 |
| **2** | **Dive 1 (LK-048)** | | | | |
| | 1 | Deploy ROV. USBL Beacon 1 on ROV, Beacon 2 on TMS. | 09/16 22:50 | 0:10 | 09/16 23:00 |
| | 2 | Test systems at 50 m, 100 m, 200 m, 415 m, 431 m on bottom. Test Beacons 3 and 4 over the side. | 09/16 23:00 | 1:06 | 09/17 00:06 |
| | 3 | Undock and operate on bottom | 09/17 00:06 | 0:10 | 09/17 00:16 |
| | 4 | Ascend, test at 50 m | 09/17 00:16 | 0:19 | 09/17 00:35 |
| | 5 | Recover | 09/17 00:35 | 0:10 | 09/17 00:45 |
| **3** | **Transit to Station Aloha** | | | | |
| | 1 | Transit | 09/17 00:45 | 10:15 | 09/17 11:00 |
| | 2 | Repair ROV | 09/17 11:00 | 2:00 | 09/17 13:00 |
| | 3 | Establish DP position (A-frame of ship) 100 m S of Cable Termination (CT), test USBL beacons | 09/17 13:00 | 0:30 | 09/17 13:30 |
| **4** | **ROV Dive 2 (LK-049)** | | | | |
| | 1 | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/17 13:30 | 0:10 | 09/17 13:40 |
| | 2 | Test ROV periodically on way down. TMS hydraulics unloaded, probably leak on TMS hydraulics. 3670 m, commenced recovery. | 09/17 13:40 | 2:24 | 09/17 16:04 |
| | 3 | Lost TMS telemtry at 3045 m, come up | 09/17 16:04 | 1:33 | 09/17 17:37 |
| | 4 | Recover ROV | 09/17 17:37 | 0:10 | 09/17 17:47 |
| **5** | **Repair ROV** | | | | |
| | 1 | Repair ROV, replumb to separate hydraulic and electrical reservoirs | 09/17 17:47 | 15:17 | 09/18 09:04 |
| **6** | **ROV Dive 3 (LK-050)** | | | | |
| | 1 | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/18 09:04 | 0:10 | 09/18 09:14 |
| | 2 | Test ROV periodically on way down | 09/18 09:14 | 2:14 | 09/18 11:28 |
| | 3 | Quad thrusters not working, at 3500 m, come up | 09/18 11:28 | 2:04 | 09/18 13:32 |

| | | | | | |
|---|---|---|---|---|---|
| | 4 | Recover | 09/18 13:32 | 0:10 | 09/18 13:42 |
| **7** | **Repair ROV** | | | | |
| | 1 | Repair ROV - opened control can | 09/18 13:42 | 5:33 | 09/18 19:15 |
| **8** | **ROV Dive 4 (LK-051)** | | | | |
| | **1** | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/18 19:15 | 0:10 | 09/18 19:25 |
| | 2 | Test ROV periodically all the way down | 09/18 19:25 | 2:53 | 09/18 22:18 |
| | 3 | Operate on bottom at 4728 m, orient, interact with shore | 09/18 22:18 | 0:56 | 09/18 23:14 |
| | 4 | Lost ROV telemetry, come up | 09/18 23:14 | 2:30 | 09/19 01:44 |
| | 5 | Recover; 3130 m regained ROV telemetry | 09/19 01:44 | 0:07 | 09/19 01:51 |
| **9** | **Repair ROV** | | | | |
| | 1 | Repair ROV | 09/19 01:51 | 5:29 | 09/19 07:20 |
| **10** | **ROV Dive 5 (LK-052)** | | | | |
| | **1** | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/19 07:20 | 0:10 | 09/19 07:30 |
| | 2 | Test ROV periodically all the way down | 09/19 07:30 | 2:53 | 09/19 10:23 |
| | 3 | Operate on bottom at 4728 m, orient, interact with shore | 09/19 10:23 | 1:35 | 09/19 11:58 |
| | 4 | Lost too much TMS electrical comp oil, come up | 09/19 11:58 | 2:30 | 09/19 14:28 |
| | 5 | Recover | 09/19 14:28 | 0:07 | 09/19 14:35 |
| **11** | **Repair ROV** | | | | |
| | 1 | Repair ROV | 09/19 14:35 | 8:28 | 09/19 23:03 |
| **12** | **ROV Dive 6 (LK-053)** | | | | |
| | **1** | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/19 23:03 | 0:10 | 09/19 23:13 |
| | 2 | Test ROV periodically | 09/19 23:13 | 0:42 | 09/19 23:55 |
| | 3 | Recover due to low electrical comp on TMS | 09/19 23:55 | 0:22 | 09/20 00:17 |
| | 4 | Recover | 09/20 00:17 | 0:10 | 09/20 00:27 |
| **13** | **Repair ROV** | | | | |
| | 1 | Repair ROV | 09/20 00:27 | 2:15 | 09/20 02:42 |
| **14** | **ROV Dive 7 (LK-054), and BSP2** | | | | |
| | **1** | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/20 02:42 | 0:10 | 09/20 02:52 |
| | 2 | Test ROV at 100 m | 09/20 02:52 | 1:00 | 09/20 03:52 |
| | 3 | Deploy BSP2 free fall, with USBL Beacon 3, 66 m/min | 09/20 03:52 | 1:12 | 09/20 05:04 |
| | 4 | ROV continues down | 09/20 05:04 | 1:09 | 09/20 06:13 |
| | 5 | Land on bottom and orient and locate | 09/20 06:13 | 0:10 | 09/20 06:23 |

| | | | | | |
|---|---|---|---|---|---|
| | 6 | Move to BSP2, ship too | 09/20 06:23 | 0:10 | 09/20 06:33 |
| **15** | **Prepare BSP2 and remove LIGHT1 connector** | | | | |
| | 1 | Remove descent weight from BSP2, remove beacon and put in basket | 09/20 06:33 | 0:14 | 09/20 06:47 |
| | 2 | Put lanyard loop on ROV basket hook | 09/20 06:47 | 0:41 | 09/20 07:28 |
| | 3 | Lift BSP2 and move to desired location ~40 m WSW from OBS, per navigator | 09/20 07:28 | 0:59 | 09/20 08:27 |
| | 4 | Remove one pin from hose reel from BSP2 | 09/20 08:27 | 0:29 | 09/20 08:56 |
| | 5 | Move to OBS to remove LIGHT1 connector from port E1 | 09/20 08:56 | 0:37 | 09/20 09:33 |
| | 6 | Remove LIGHT1 connector from port E1 | 09/20 09:33 | 0:02 | 09/20 09:35 |
| | 7 | Put pin protecting dummy on LIGHT1 connector and clear BSP1 cable | 09/20 09:35 | 0:29 | 09/20 10:04 |
| | 8 | Redock ROV, lights failed, and ascend at 40 m/min | 09/20 10:04 | 2:04 | 09/20 12:08 |
| | 9 | Recover | 09/20 12:08 | 0:10 | 09/20 12:18 |
| **16** | **Repair ROV** | | | | |
| | 1 | Repair ROV | 09/20 12:18 | 5:15 | 09/20 17:33 |
| **17** | **ROV Dive 8 (LK-055), LIGHT4** | | | | |
| | 1 | Deploy ROV. Beacon 1 on ROV, Beacon 2 on TMS. | 09/20 17:33 | 0:07 | 09/20 17:40 |
| | 2 | Test ROV at 100 m | 09/20 17:40 | 0:27 | 09/20 18:07 |
| | 3 | Deploy LIGHT4 free fall, with USBL Beacon 3 (lost track at 2330 m) | 09/20 18:07 | 1:12 | 09/20 19:19 |
| | 4 | ROV continues down (some time just above) | 09/20 19:19 | 1:09 | 09/20 20:28 |
| | 5 | Set down near BSP2 and orient | 09/20 20:28 | 0:05 | 09/20 20:33 |
| | 6 | Fly to BSP2 | 09/20 20:33 | 0:03 | 09/20 20:36 |
| **18** | **Connect BSP2** | | | | |
| | 1 | Transfer weights from basket to BSP2 | 09/20 20:36 | 0:42 | 09/20 21:18 |
| | 2 | Remove second pin from axle | 09/20 21:18 | 0:05 | 09/20 21:23 |
| | 3 | Shot bag on beacon tube | 09/20 21:23 | 0:16 | 09/20 21:39 |
| | 4 | Pull out reel | 09/20 21:39 | 0:24 | 09/20 22:03 |
| | 5 | Fly towards BSP1 paying out hose | 09/20 22:03 | 0:29 | 09/20 22:32 |
| | 6 | At end of hose, remove connector from reel and leave reel | 09/20 22:32 | 0:33 | 09/20 23:05 |
| | 7 | Take BSP2 connector to port E1 on SE corner 3 of OBS | 09/20 23:05 | 0:33 | 09/20 23:38 |
| | 8 | Remove pin-protecting dummy | 09/20 23:38 | 0:17 | 09/20 23:55 |
| | 9 | Plug BSP2 connector into port E1 | 09/20 23:55 | 0:52 | 09/21 00:47 |
| | 10 | Have shore turn on BSP2 and test | 09/21 00:47 | 0:10 | 09/21 00:57 |
| **19** | **Go to LIGHT4** | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | 1 | Move to LIGHT4 | 09/21 00:57 | 0:54 | 09/21 01:51 |
| | 2 | TMS Hydraulic comp low, lost pressure | 09/21 01:51 | 0:00 | 09/21 01:51 |
| **20** | **Ascent and Recovery, end ROV Dive 8 (LK-055)** | | | | |
| | 1 | ROV ascends | 09/21 01:51 | 1:57 | 09/21 03:48 |
| | 2 | Recover ROV | 09/21 03:48 | 0:10 | 09/21 03:58 |
| **21** | **Recover Seaglider** | | | | |
| | 1 | Locate | 09/21 03:58 | 1:32 | 09/21 05:30 |
| | 2 | Recover | 09/21 05:30 | 1:30 | 09/21 07:00 |
| **22** | **Transit to Honolulu** | | | | |
| | 1 | Transit | 09/21 07:00 | 10:00 | 09/21 17:00 |
| | 2 | Holding off Honolulu for entry | 09/21 17:00 | 1:00 | 09/21 18:00 |
| | 3 | Arrive | 09/21 18:00 | 0:00 | 09/21 18:00 |
| | | | **09/16 20:30** | **117.5** | **09/21 18:00** |
| | | | | **4.90** | |