NOAA *Ocean Exploration*

MAPPING DATA ACQUISITION AND PROCESSING REPORT

CRUISE EX-16-03

Hohonu Moana 2016: Exploring the Deep Waters off Hawai'i expedition (Part of the CAPSTONE project)
(ROV and Mapping)

February 23 to March 18, 2016
Honolulu, HI – Kwajalein, Marshall Islands

Report Contributors:
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March 20, 2015

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1. Introduction

NOAA Ship *Okeanos Explorer*

Commissioned in August 2008, the NOAA Ship *Okeanos Explorer* is the nation's only federal vessel dedicated to ocean exploration. With 95% of the world's oceans left unexplored, the ship's combination of scientific and technological tools uniquely positions it to systematically explore new areas of our largely unknown ocean. These exploration cruises are explicitly designed in collaboration with the broad science community to provide a foundation of publicly accessible baseline data and information to support science and management needs. This baseline information often leads to further, more detailed, investigations by other parties.

The unique combination of mission capabilities including a high-resolution multibeam sonar, deep water remotely operated vehicles, telepresence technology, and integrated data management system quicken the scientific discovery and dissemination process. These systems enable us to identify new targets in real time, dive on those targets shortly after initial detection, and then send this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The integrated data management system provide for the quick dissemination of information-rich products to the scientific community. This ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis.

Through the operation and maintenance of the mission capabilities, NOAA's Office of Ocean Exploration and Research (OER) provides the nation with unparalleled capacity to discover and investigate new oceanic regions and phenomena, conduct baseline research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. OER strives to develop technological solutions and innovative applications to critical problems in undersea exploration and to provide resources for developing, testing, and transitioning solutions to meet these needs.

Okeanos Explorer Management – a unique partnership within NOAA

The *Okeanos Explorer* combines the capabilities of a NOAA research ship with shore-based high speed networks and infrastructure to conduct systematic telepresence-enabled exploration of the world ocean. The ship is operated, managed and maintained by NOAA's Office of Marine and Aviation Operations, which includes commissioned officers of the NOAA Corps and civilian wage mariners. OER owns and is responsible for operating and managing the cutting-edge ocean exploration systems on the vessel (ROV, mapping and telepresence) and ashore including Exploration Command Centers and terrestrial high speed networks. The ship and shore-based infrastructure combine to be the only federal program dedicated to systematic telepresence-enabled exploration of the planet's largely unknown ocean.

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2. Report Purpose

The purpose of this report is to briefly describe the mapping data collection and processing methods, and to report the results of the mapping portion of the cruise. For a detailed description of *Okeanos Explorer* mapping capabilities, see the appendices section 'Kongsberg EM 302 Multibeam Sonar Desciption and Operational Specifications' and the ship's readiness report, which can be obtained by contacting the Okeanos Explorer Mapping Team (oar.oer.exmappingteam@noaa.gov).

This report focuses on the mapping exploration of EX-16-03. The cruise was a combined ROV exploration and mapping of the Papahānaumokuākea Marine National Monument (PMNM) including areas inside and outside the monument as well as operations in international waters and inside the Marshall Islands.

3. Cruise Objectives

The cruise objectives for EX-16-03 were defined in EX-16-03 Project Instructions. EX-16-03 operations included collecting baseline-characterization data of poorly known areas over a wide area of the US EEZ around the Hawaiian Island Chain, focusing primarily in and around Papahānaumokuākea Marine National Monument (PMNM). The mapping specific objectives included the following:

a. Collect high resolution mapping data from all sonars in priority areas as dictated by operational needs as well as science and management community needs;

b. Support ROV operations with mapping products and expertise;
c. Conduct mapping operations during transit, with possible further development of exploration targets;
d. Collect XBT/ underway CTD casts at regular intervals as data quality requires, during mapping operations;
e. Create daily standard mapping products;
f. Collection of sun photometer measurements as part of survey of opportunity;
g. Continue to test the integration of the new EK60 frequencies and the ADCPs. Overnight mapping operations will focus on refining protocols for the new sonars.

All objectives were achieved except objectives f and g.

Overall Data Collection Objectives

During EX 16-03, ROV operations were conducted during the day light hours. Mapping operations were conducted during night time, during inclement weather when ROV operations were suspended and while transiting between ROV dive locations. Transits between the dive target sites were primarily over previously mapped seafloor carried out during *Okeanos Explorer* cruises EX-15-04 and Falkor 2014 cruises. Transit mapping focused on filling in any holidays in the existing datasets. Multibeam, single beam, and sub-bottom profile data was generally collected for 12 hours during overnight transits between dive target sites. Expendable bathythermograph (XBT) casts were conducted at an interval defined by prevailing oceanographic conditions, generally every four to six hours. All multibeam sonar bathymetric data were fully processed according to established onboard procedures. Multibeam sonar seafloor backscatter and water column backscatter, Knudsen sub-bottom profiler and EK 60 data were sporadically processed to support ROV operations but no systematic effort was made to process all the seafloor and water column backscatter due to lack to mapping staffing during this cruise. All multibeam data along with ancillary sonar datasets will be archived at National Centers for Environmental Information (NCEI) formerly known as National Oceanographic Data Center or the National Geophysical Data Center.

4. Participating Mapping Personnel

NAME	ROLE	AFFILIATION
CDR Mark Wetzler	Commanding Officer	NOAA Corps
ENS Pestone	Field Operations Officer	NOAA Corps
Brian Kennedy	Expedition Coordinator	NOAA OER (GFOE)
Mashkoor Malik	Mapping Team Lead	NOAA OER
Jason Meyer	Watch Lead	NOAA OER (UCAR)
Walter Potts	Watch Lead	NOAA

5. Summary of Major Findings

Cruise Map

The mapping focused around the monument is shown in the over overall map (Figure 1). The background shows the NOAA Nautical chart. Existing Multibeam bathymetry collected during 2014-2015 NOAA Ship *Okeanos Explorer* and R/V Falkor are shown as grey color. Dive locations from NOAA *Okeanos Explorer* conducted during the current cruise and in 2015 are also shown.

Mapping Statistics

Dates	February 25 – March 18, 2016
Days lost to weather	Weather was too rough for mapping for 6 days
Total mapping days	0 days – Mapping conducted to support ROV operations / during rough weather while ROV operations were not possible
Total non-mapping days	N/A
Line kilometers of survey	~6164 km
Square kilometers mapped	38,690 km^2
Number / Data Volume of EM 302 raw bathymetric / bottom backscatter multibeam files	~415 files /115 GB
Number / Data Volume of EK 60 water column singlebeam files	files / GB
Number / Data Volume of subbottom sonar files	files / GB
Number of XBT casts	40
Number of CTD casts (including test casts)	0
Number of ROV dives conducted	13
Beginning draft	N/A
Ending draft	N/A
Average ship speed for survey	8.47 kts

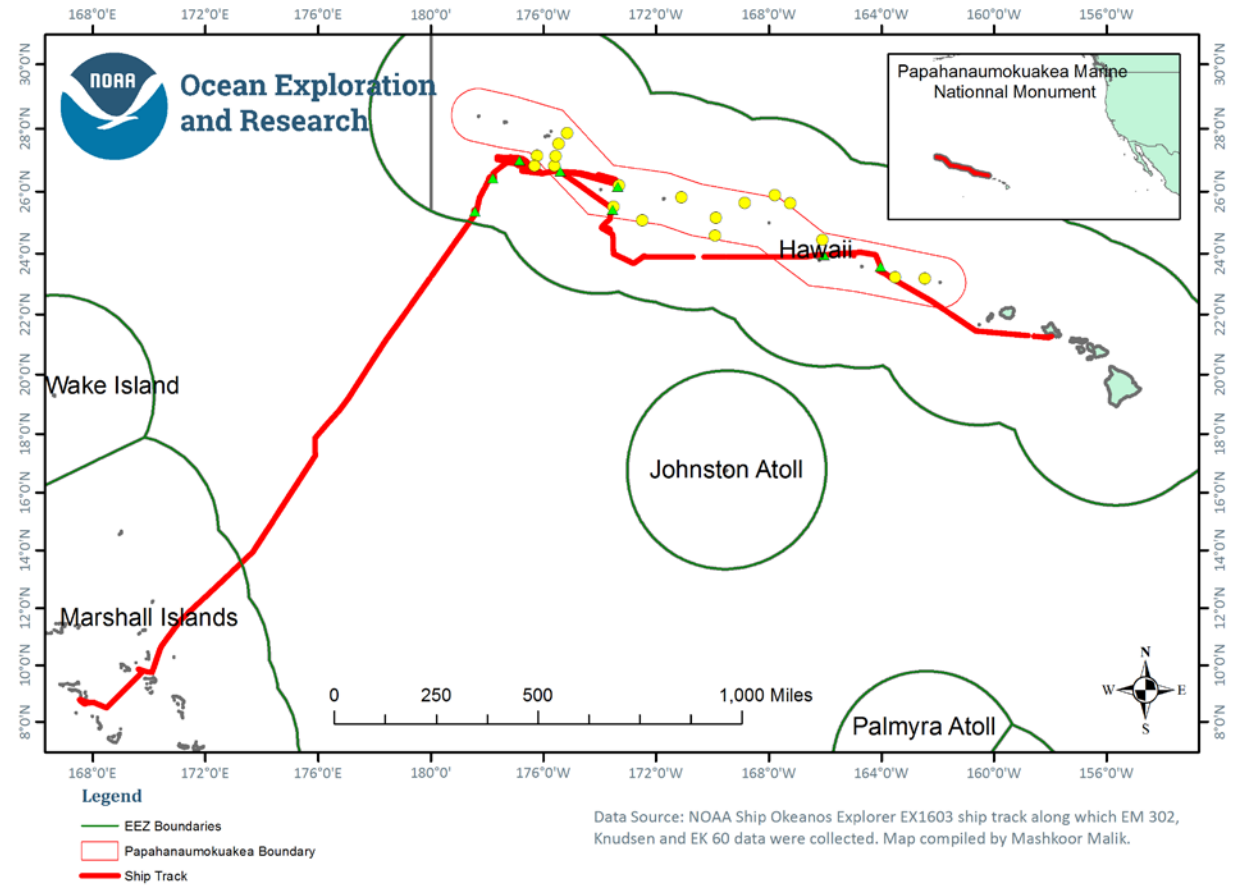

Figure 1. Cruise track of EX1603 from Honolulu, HI to Kwajalein, Marshall Island.

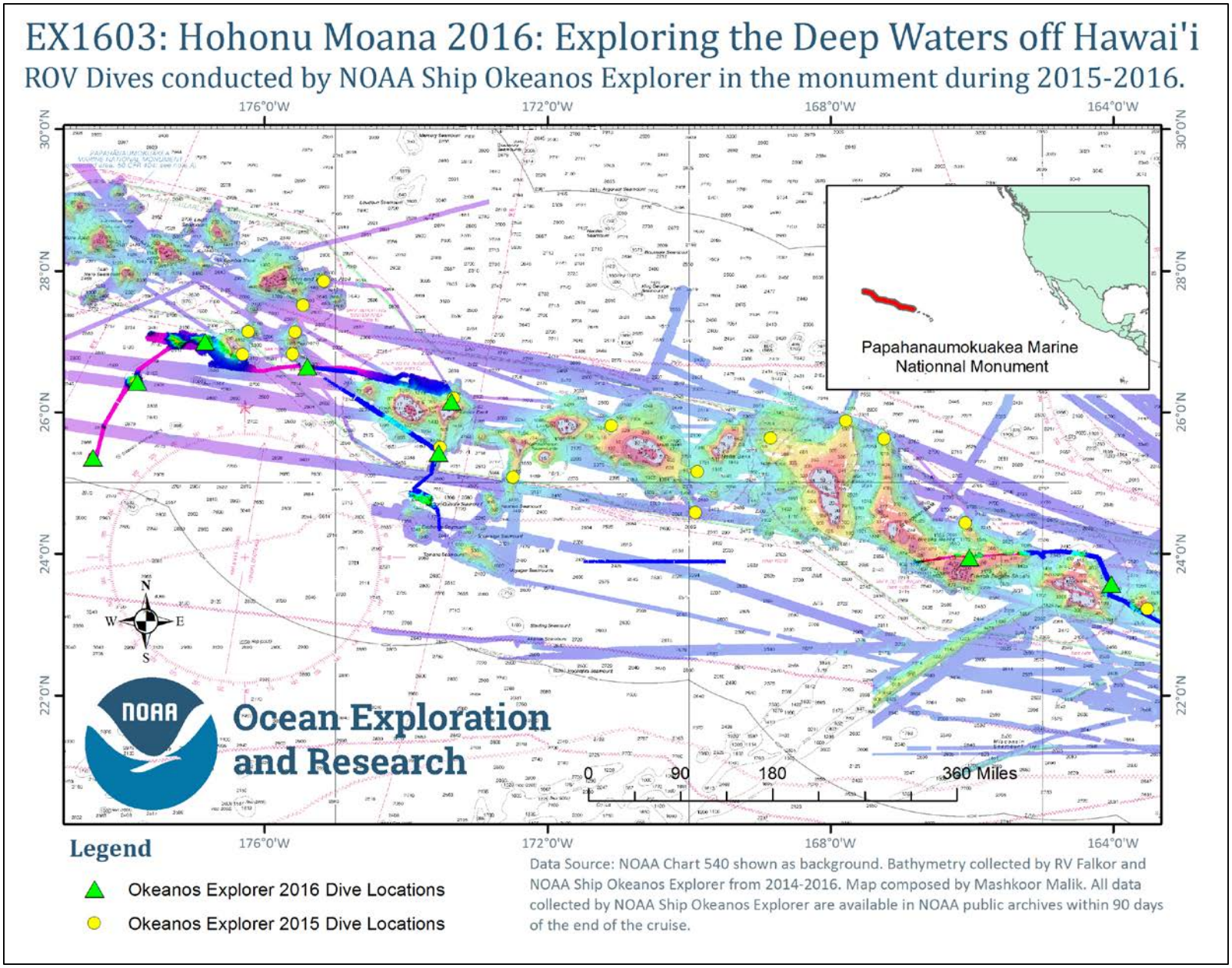

Figure 2. Cruise map showing overall cumulative multibeam sonar coverage after EX1603 along with dives conducted in the monument by OER during 2015 and 2016 expeditions.

Features of Interest

Several seamounts were mapped in details for the first time during this expedition. These included adding coverage over Don Quixote seamount, and several unnamed seamounts. With in monument, a seamount was mapped that was known to exist based on satellite derived bathymetry. Other seamounts were targeted for mapping based on satellite derived data with in monument and during the transit to Kwajalein.

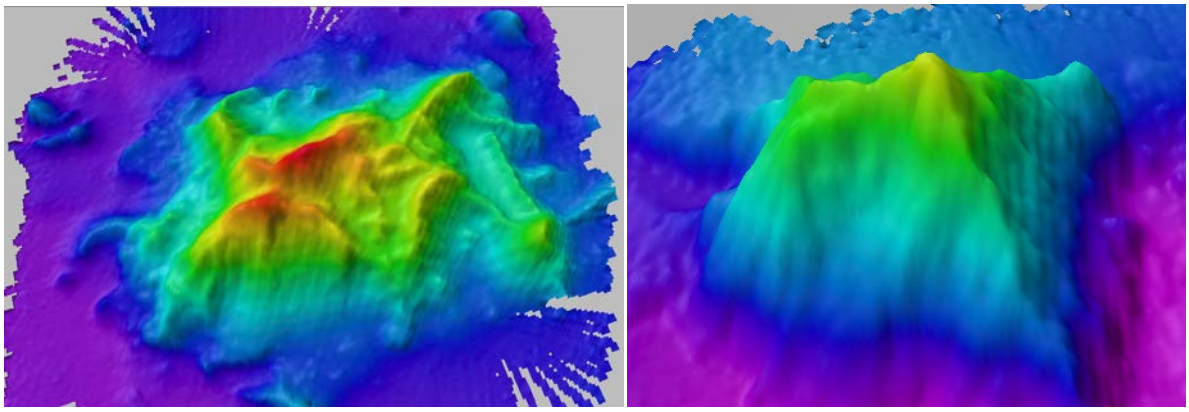

Figure 3: 3D screen shots of two of the seamounts that were mapped during expedition.

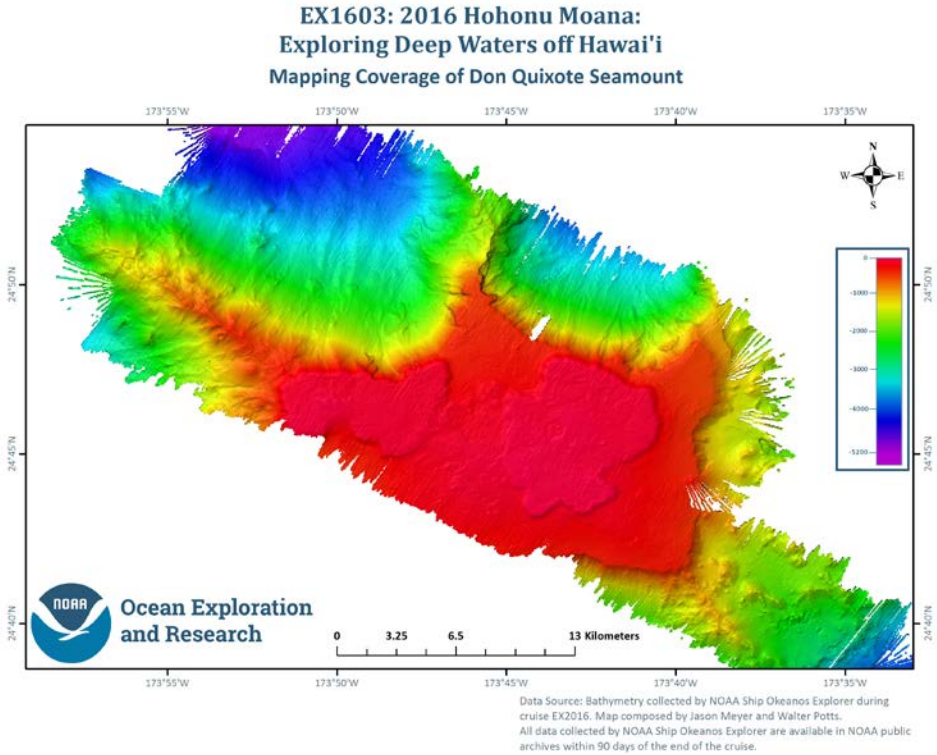

Figure 4. Mapping coverage over Don Quixote Seamount.

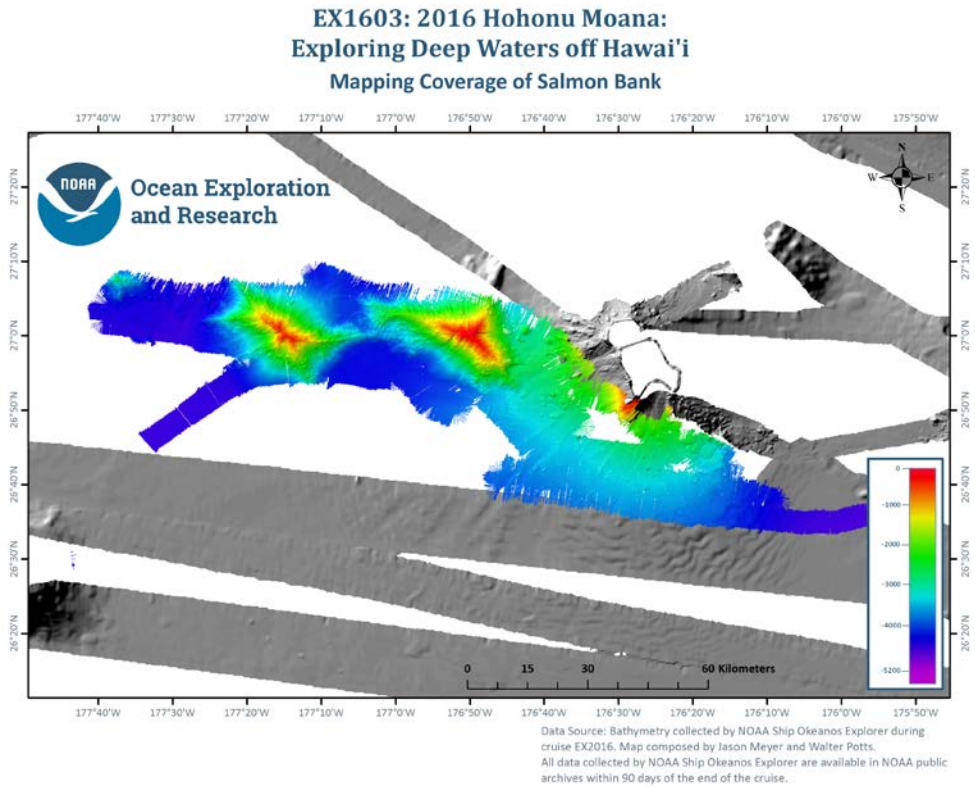

Figure 5. Mapping coverage over unnamed seamounts in vicinity of Salmons Bank.

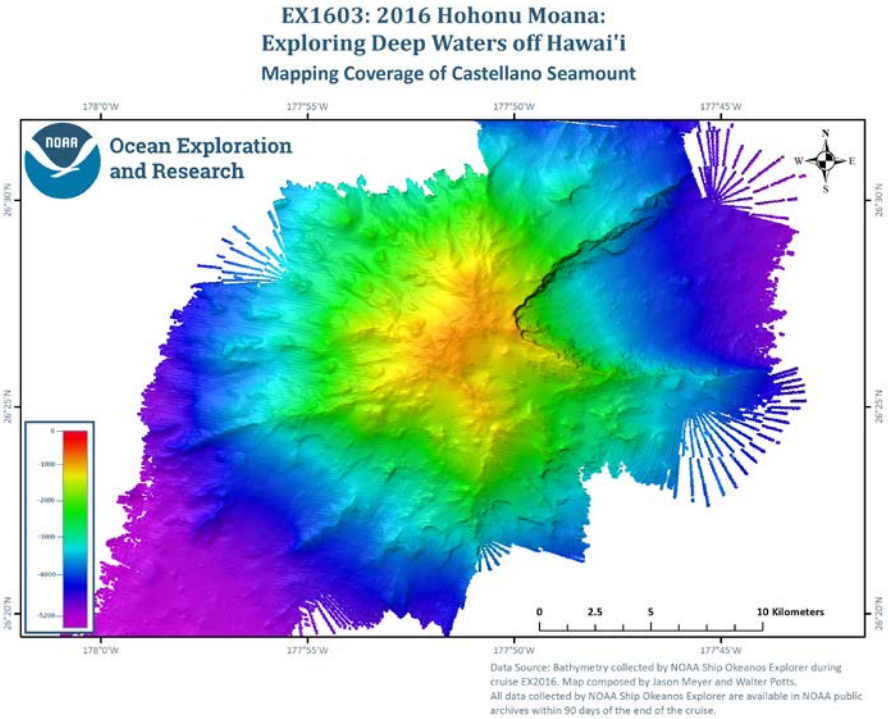

Figure 6. Mapping coverage over Castellano seamount.

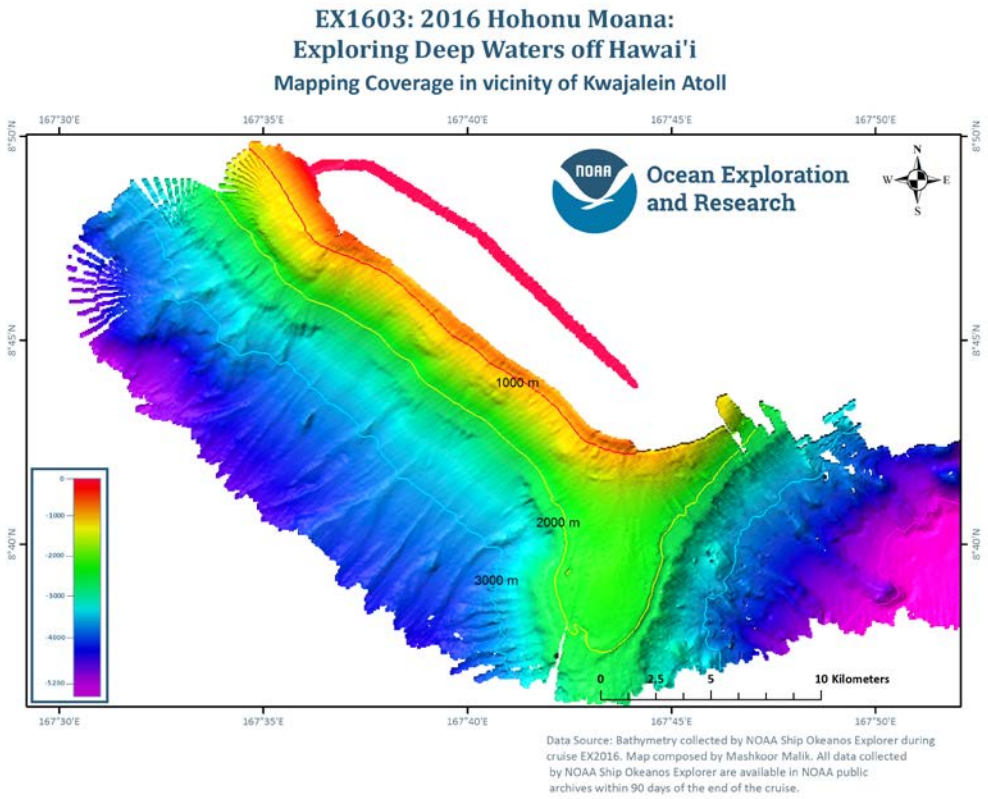

Figure 7. Mapping coverage over Castellano seamount.

6. Mapping Sonar Setup

The NOAA Ship *Okeanos Explorer* is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar capable of mapping the seafloor in 0 to 8000 meters of water. The system generates a 150° beam fan containing up to 432 soundings per ping in waters deeper than 3000 meters. In waters less than 3000 meters, the system is operated in multiping, or dual swath mode, and obtains up to 864 soundings per ping, by generating two swaths per ping cycle.

The ship is also equipped with Kongsberg EK 60 singlebeam fisheries sonar. The following frequencies of EK 60 were available during the expedition: 18, 70, 120 and 200 kHz. Additionally the ship is equipped with a Knudsen 3260 subbottom profiler that produce a 3.5 kHz chirp signal and two acoustic Doppler current profiler (ADCP) operating at 38 and 300 kHz frequency. ADCP were recently installed in January 2016 and currently are not synchronized with EM 302. Therefore ADCP were not operated concurrently with EM 302.

7. Data Acquisition Summary

EX-16-03 operations included EM 302 multibeam, EK 60 singlebeam, Knudsen subbottom profile and ADCP data collection. The schedule of operations included ~ 12-hour overnight

mapping data collection, weather permitting. Additionally, mapping operations were conducted during the days when ROV dives were canceled. The multibeam coverage can be seem in Figure 1.

Expendable bathythermographs were collected every four to six hours to correct multibeam data for changes in sound speed in the water column, and were applied in real time using Seafloor Information Software (SIS). Sound speed at the sonar head was determined using a Reson SVP-70 probe and the thermosalinograph (TSG). Data from these two systems was monitored for consistency throughout the cruise, and whichever was performing better was applied in realtime using SIS.

Background data used for operational planning included existing multibeam data collected by *the Okeanos Explorer* and R/V *Falkor*, and Sandwell and Smith satellite altimetry bathymetric data.

8. Sonar Data Quality Assessment and Data Processing

Throughout the cruise, multibeam data quality was monitored in realtime by acquisition watchstanders. XBTs were conducted every three to six hours as necessary to maintain data quality. Starting 14 March, EM 302 started loosing lock on PPS signal from POS –MV. The problem resulted in large PU-ZDA time offsets. The issue was observed to exacerbate during evening and night hours. At writing of this report, the issue is still being investigated with help from POS MV. Diagnostic data has been sent to POS MV.

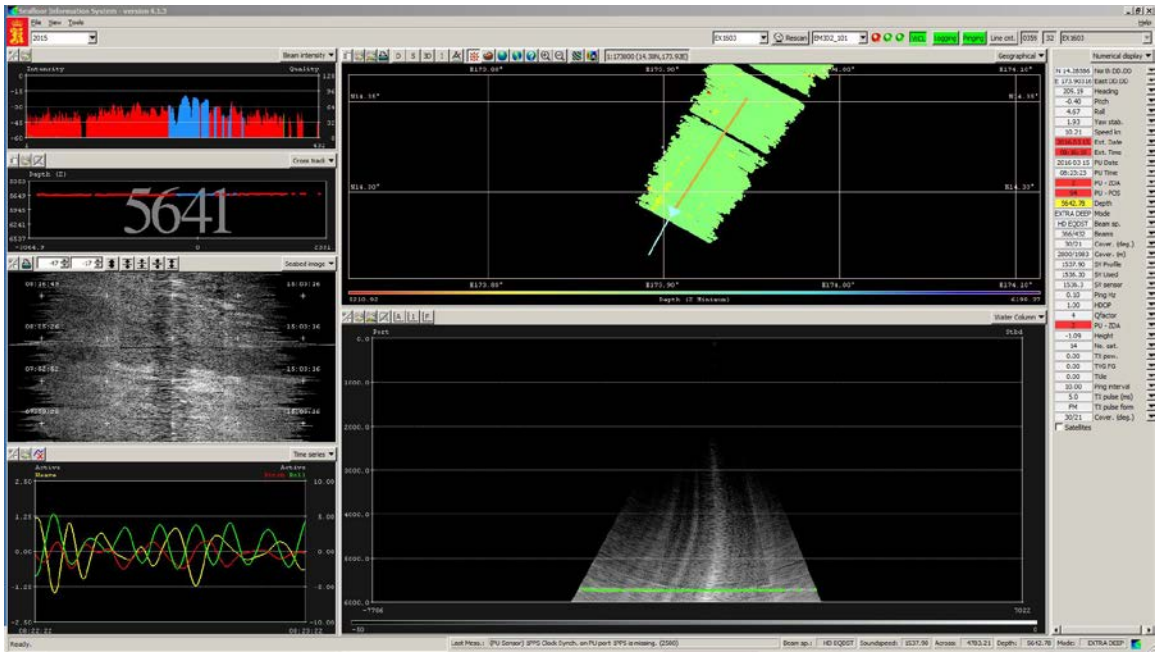

Figure 8. The screen shot of EM 302 SIS display showing time error.

ADCP (38 kHz) was observed to cause significant interference with EM 302 resulting in bad bottom detections. ADCP (300 kHz) was also unexpectedly observed to interfere with EM 302.

The interference with ADCP (300 kHz) increased noise in the STBD sector of EM 302 (Figure 9,10). It is recommended that cause of this interference be investigated further as EM 302 (30 khz) and ADCP (300 kHz) are not expected to interfere acoustically.

Figure 9: The water column display of EM 302 showing interference pattern with ADCP (both 38 kHz and 300 kHz) on.

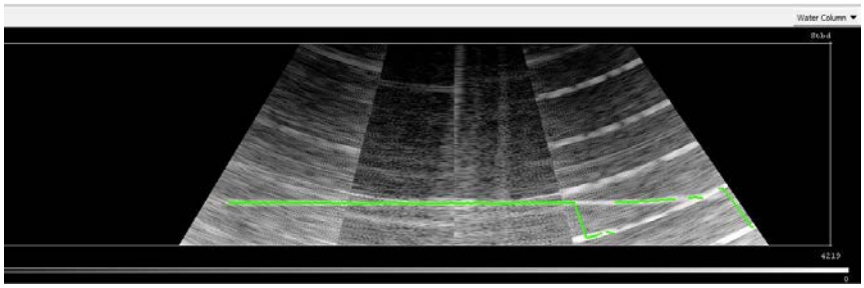

Figure 10. The water column display of EM 302 showing interference pattern with only 300 kHz ADCP.

Raw multibeam bathymetry data files were acquired by SIS, and were imported into CARIS. In CARIS, attitude and navigation data stored in each file were checked, and erroneous soundings were removed using CARIS Subset Editor. Once per day, cleaned, gridded bathymetric data were exported to ASCII text files (y,x,z) at 100 meter cell size in WGS84 datum. The ASCII files were then used to create Fledermaus SD objects. These SD objects were then exported to geotiff and Google Earth KMZ, which were copied to the shoreside FTP on a daily basis for analysis by shoreside scientist.

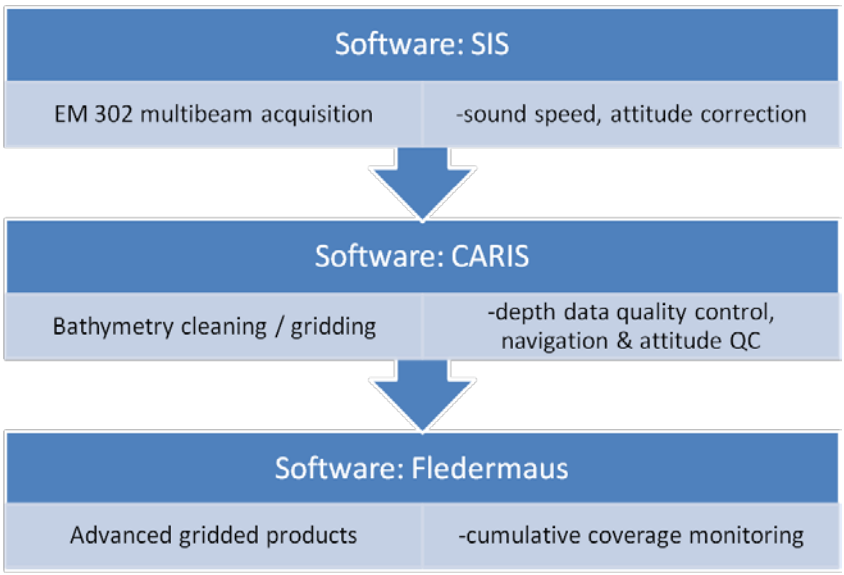

Figure 9. Shipboard multibeam data flow.

The EM302 was only shut down once during the entire cruise, during a 24-hour weather transit to shallow water.

EM 302 Built In System Tests (BISTs)

Prior to this cruise, EM 302 CPU board was replaced. During this cruise regular BISTs were run but no errors were detected. Thirteen built in system tests (BIST) were run during the cruise to monitor the system health of the EM 302 sonar electronics. BIST files will be archived along with EM 302 raw data files.

9. Data Archival Procedures

All mapping data collected by *Okeanos Explorer* are archived and publically available within 90 days of the end of each cruise via the National Centers for Environmental Information (NCEI) formerly known as National Geophysical Data Center's (NGDC). Data can be accessed via the following website (last accessed 11/09/2015):

- the NGDC Interactive Bathymetry Data Viewer at http://maps.ngdc.noaa.gov/viewers/bathymetry/

The complete EX-16-03 *Okeanos Explorer* data management plan is provided in the appendices of this report.

10. Telepresence

A 20 mb/s ship-to-shore connection was available throughout the cruise.

Live video was available throughout the cruise on the Ocean Explorer Website. http://oceanexplorer.noaa.gov/okeanos/media/exstream/exstream.html.

11. Cruise Calendar.

All times listed are in UTC. Local ship time was -4 hours from UTC.

February / March 2016						
Sun	Mon	Tues	Wed	Thur	Fri	Sat
2/21 Seafloor Mosaic Display was installed.	2/22 Ongoing preparations for departure.	2/23 Departure delayed. Ongoing preparations for departure.	2/24 Departure delayed	2/25 Departed 1500 local time	2/26 Continue transit towards ROV dive site in vicinity of the monument.	2/27 During day conducted ROV operations. In transit mapping over night to next dive site.
2/28 Conducted ROV operations. Weather prediction to be bad over night. Ship started heading west. Mapping sonars secured due to poor data quality.	2/29 Weather deteriorated forcing the ship to exit the monument and head towards west	3/1 Weather continues to be bad. Ship continued heading towards west and then transited north to conduct mapping operations over Don Quixote seamount in transit to Pioneer Bank.	3/2 Conducted ROV operations in vicinity of Pioneer Bank.	3/3 In transit mapping to next ROV dive site. ROV dive cancelled due to weather. Over day mapping conducted.	3/4 ROV operations during day. In transit mapping over night.	3/5 ROV operations during day. In transit mapping over night.
3/6 Weather continues to deteriorate.	3/7 Rough weather. Mapping in vicinity of Salmons bank with following seas.	3/8 Rough weather. Mapping in vicinity of Salmons bank with following seas.	3/9 ROV operations during day.	3/10 ROV operations during day.	3/11 ROV operations during day. Commenced transit to Kwajalein.	3/12 In transit mapping to Kwajalein.
3/13 In transit mapping to Kwajalein.	3/14 In transit mapping to Kwajalein.	3/15 In transit mapping to Kwajalein.	3/16 In transit mapping to Kwajalein.	3/17 Arrived Kwajalein	3/18	

12. Daily Cruise Log

February 23-25, 2016

Departure from Honolulu, HI enroute to PMMN monument was delayed. During inport work on installing Seafloor Mosaic Display (SMD) – a software developed by Roger Davis of University of Hawaii was completed. SOPs for SMD was also developed. At this time, it is not clear how SMD would be utilized in mapping data acquisition and processing workflow. The software receives data over UDP from EM 302 and constructs real time bathymetric and backscatter mosaics.

February 25, 2016

The ship departed Honolulu at 1500 local time; survey personnel started all sonar systems at the sea buoy. The ship was traveling North Northeast, in route to Papahanaumokuakea Marine National Monument (PMNM) and the first target/location for ROV exploration. The Systems aboard pinging and logging included the Kongsberg EM302 multibeam sounder (SYS), the Simrad EK60 multibeam sounder (EK60), the Knudsen sub-bottom profiler, and the Teledyne Acoustic Doppler Current Profiler (ADCP). Personnel assigned to the mapping area included, Mashkoor Malik , Mapping Watch Lead Jason Meyer, and Survey Technician Walter Potts. All of the sonar systems were functioning normally as the ship departed Pearl Harbor, Honolulu, Hawaii.

February 26, 2016
The day was spent transiting to the first ROV dive site, collecting sonar data during the transit. The daily product was completed and included in the data package. The data quality was fair.

February 27, 2016
Priority Survey line (line 35) was complete at 04:43; the ship arrived at the first ROV dive site at 06:17. The sonar equipment was secured during the ROV dive and re-started after departure at 17:37. Data collection continued along track as the ship transited to second dive site. The daily product was completed and included in the data package.

February 28, 2016
Data collection along the ships track line continued overnight, the ship arrived at ROV dive site two at 06:38, all sonar equipment was secured upon arrival. The ship departed the ROV dive site at 16:28 and all sonar equipment was re-started, with severe weather moving into the area the ship headed west, initially collecting data along the ships track line. The sonar equipment was secured at 20:49, due to the severe weather and poor data quality

February 29, 2016
The sonar equipment was started at 11:17, the data was of poor quality as the ship continued on its track line avoiding the worst of the severe weather. The sonar equpment was secured at 22:15

March 01, 2016
The sonar equipment was started at 08:26, the ship was still in severe weather and the data quality was poor. Stopped logging at 11:10. Re-started acusition of all sonar equipment at 12:54. Coverage for a holiday at Don Quixote Seamount was aquired at 17:09. Sonar aquisition continued throughout the rest of the day with acceptable data quality.

March 02, 2016
Data collection was continued from the prior day, the data quality was good. Data collection over the Don Quixote seamount ended at 1:26. Arrived at Pioneer Bank ROV dive site at 06:19, all sonar equipment was secured. Data acquisition was re-started after the ROV dive at 19:14.

March 03, 2016

ROV dive operations cancelled due to weather. Logging continued from the previous day, data gaps occuring due to severe weather late in the watch. Data collected during day and over night.

March 04, 2016
Conducted ROV operations during day. Conducted in transit mapping to the next ROV dive site. All Sonar pinging and logging. Data quality remains satisfactory.

March 05, 2016
Mapping the ships transit line overnight, all of the sonars were pinging and logging. Arrived at the ROV dive site at 06:30 and mapping sensors were secured. Mapping began again at 17:40 after the ROV dive. Data quality deteriorated into the evening as wind and wave height increased.

March 06, 2016
Severe weather moving through, wind and wave heights increased. Mapping was interrupted at 09:20 the ship was maneuvering attempting to find the best ride for the weather conditions. Pinging and logging resumed at 13:30, as the ship headed for Salmon Bank Seamount. The severe weather continued into the night with 20' seas and 50kt+ gusts of wind.

March 07, 2016
Severe weather continued to interrupt operations, no ROV dive, Multibeam collection attempted for most of the day, but stopped at 15:57, the SIS application stopped responding, BIST was run, Pinging and logging were resumed 16:06. Data quality was poor early in the day but with improving weather and ships direction in favor of mapping, the data did improve during the evening. Mapping un-named seamount though the evening and overnight.

March 08, 2016
Mapping continued through the night on the un-named seamount , due to severe weather data quality was poor at times, pinging and logging were stopped at 05:58, the ship transited to the ROV dive site, the weather prevented the dive and pinging and logging were re-started. There were problems with the Knudsen sonar finding the bottom, the weather continued to be problematic for data collection.

March 09, 2016
The wind and high seas are calming, data quality is good, during the day the Knudsen sonar was having trouble finding the bottom the system was re-started and was operating satisfactorily. Mapping continued on the two un-named seamounts, West of Salmon Bank. Arrived at the dive site at 06:00, Stopped pinging stopped logging on all sonar. All sonar started pinging and logging at 19:40 as the ship departed the dive site, and began the transit to, and mapping of tomorrows dive site.

March 10, 2016
During transit to next dive site (Castellano seamount). The dive site was mapped for the ROV deployment at the dive site upon arrival, all sonar systems were secured after mapping was completed ~ 0600. After the ROV dive was completed, the ship got underway approximately at

19:15 and departed Castellano seamount. All sonar systems began pinging and logging, data quality was good. The ship began the transit to the next ROV dive site enroute to Kwajalein.

March 11, 2016
Mapped an unnamed seamount overnight and conducted ROV operations during the day. After ROV operations were completed, the ship commenced her transit to Kwajalein. The data quality remains satisfactory.

March 12, 2016
The ship is in transit to Kwajalein, we are mapping 24 hours each day during the transit. The International Date Line was crossed at 08:44. All sonar is pinging and logging, the data quality is good.

To avoid problems with data plotting across the date line, EM 302 recording line was incremented at date line. No problems were observed in processing data in CARIS HIPS. Although SIS display did not show the correct ships heading while crossing date line (Figure ?) the resulting data showed no errors.

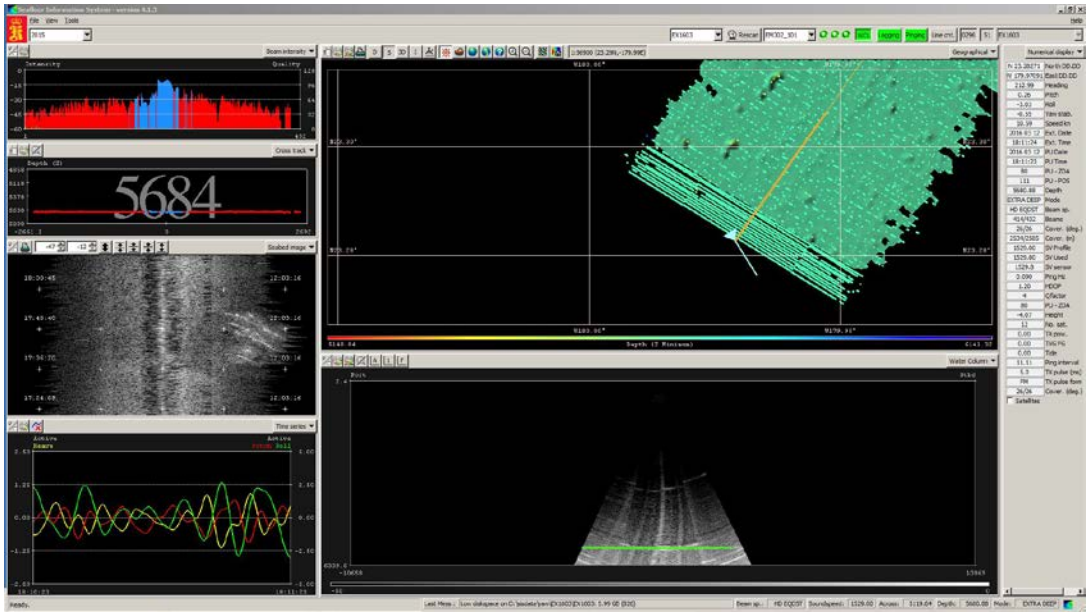

Figure 11. Shipboard multibeam data flow.

March 13, 2016
The ship continues to transit to Kwajalein, we are mapping 24 hours each day during the transit. The data quality is fair to good. There have been some sync errors, but they do not seem to be affecting the data.

March 14, 2016

The ship continues to transit to Kwajalein, we are mapping 24 hours each day during the transit. The data quality is fair to good. A problem with the sync between CNAV and the POS MV, is still causing sync errors, but the data appears to remain unaffected.

March 15, 2016
The ship continues to transit to Kwajalein, we are mapping 24 hours each day during the transit. The data quality is fair to good. There have been some sync errors, but they do not seem to be affecting the data.

March 16, 2016
The ship continues to transit to Kwajalein, we are mapping 24 hours each day during the transit. The data quality is fair to good. There have been some sync errors, but they do not seem to be affecting the data.

March 17, 2016
Mapping continued during the transit overnight, with arrival in Kwajalein, all data collection was stopped and the cruise data package is being prepared.

13. References

The 2016 Survey Readiness Report can be obtained by contacting NOAA Ship *Okeanos Explorer* at ops.explorer@noaa.gov.

EX-16-03 Project Instructions can be obtained by contacting NOAA Ship *Okeanos Explorer* at ops.explorer@noaa.gov.

Appendix A: Acronyms

- AERONET – Aerosols Robotic Network
- AHB – Atlantic Hydrographic Branch
- ASCII – American Standard Code for Information Interchange
- BIST – built in system test
- CDR – Commander
- CO – Commanding Officer
- CTD – conductivity, temperature, depth
- dB - decibel
- DNP – do not process
- DP - dynamic position(ing)
- ERT – Earth Resources Technology Inc.
- ET – Electronics Technician
- EX – NOAA Ship *Okeanos Explorer*
- FM – frequency modulated / modulation
- FTP – file transfer protocol
- GB - gigabytes(s)
- KB - kilobytes(s)
- kHz – kilohertz
- km – kilometer
- kts – knots
- LT – Lieutenant
- LSS - light scattering sensor
- m - meters
- MAN – Maritime Aerosols Network
- MB – multibeam sonar
- MB – megabytes(s)
- NASA – National Aeronautics and Space Agency
- NCDDC – National Coastal Data Development Center
- NGDC – National Geophysical Data Center
- NMEA – National Marine Electronics Association
- NOAA – National Oceanic and Atmospheric Administration
- NODC – National Oceanographic Data Center
- OER – NOAA Office of Ocean Exploration and Research
- OMAO – NOAA Office of Marine and Aviation Operations
- OPS – Operations Officer
- ROV – remotely operated vehicle
- SBP – subbottom profiler
- SCS – scientific computer system
- SIS – Seafloor Information System
- SVP – sound velocity profile
- TRU – transceiver unit
- TSG - thermosalinograph
- TX – transmit boards
- USGS – United States Geological Survey
- W - watt

- XBT – expendable bathythermograph
- XO – Executive Officer