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NOAA *Okeanos Explorer* Program

MAPPING DATA REPORT

CRUISE EX1003

Exploration Mapping: Hawaii to Guam

May 19 - June 3, 2010

Honolulu, HI to Guam

Report Contributors:

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1. Introduction

The *Okeanos Explorer* Program

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 to generate hypotheses and lead to further investigations by the wider scientific community.

Using a high-resolution multibeam sonar with water column capabilities, a deep water remotely operated vehicle, and telepresence technology, *Okeanos Explorer* provides NOAA the ability to foster scientific discoveries by identifying new targets in real time, diving on those targets shortly after initial detection, and then sending this information back to shore for immediate near-real-time collaboration with scientists and experts at Exploration Command Centers around the world. The subsequent transparent and rapid dissemination of information-rich products to the scientific community ensures that discoveries are immediately available to experts in relevant disciplines for research and analysis

Through the *Okeanos Explorer* Program, 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 the basic research required to document discoveries, and seamlessly disseminate data and information-rich products to a multitude of users. The program 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* Program combines the capabilities of the NOAA Ship *Okeanos Explorer* with shore-based high speed networks and infrastructure for 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 cruise. For a detailed description of the *Okeanos Explorer* mapping capabilities, see appendix D and the ship's readiness report, which can be obtained by contacting the ships operations officer (ops.explorer@noaa.gov).

3. Cruise Objectives

The main objective of cruise EX1003 was to conduct exploration mapping between Honolulu and Guam, as the first leg of the transit to Indonesia for cruises EX1004 Legs 1, 2, 3 and 4. The planned transit route followed the great circle route.

The goals of the mapping department included collecting continuous high quality bathymetry during the entire transit, as well as assessing the following data quality issues observed following the upgrade to the new TX36 LC boards in the EM302:

- Side lobe detection observed as severe rail road tracks in waters 2000 - 4000 m
- Apparent reduced swath coverage as compared to the 2009 field season
- Apparent reduced weather threshold tolerance

Operational plans were designed to run a series of BISTs at least once a day to monitor TX and RX noise levels seen in various weather conditions and at various vessel headings and speeds. These results would then be correlated to data quality issues above. Engineering department activities were monitored to determine any possible effect on data quality.

4. Participating Personnel

NAME	ROLE	AFFILIATION
CDR Joseph Pica	Commanding Officer	NOAA Corps
LT Nicola VerPlanck	Field Operations Officer	NOAA Corps
Kelley Elliott	Expedition Coordinator	NOAA OER (20/20 Inc.)
Meme Lobecker	Mapping Team Lead	NOAA OER (ERT Inc.)
Elaine Stuart	Senior Survey Technician	NOAA OMAO
Colleen Peters	Senior Survey Technician	NOAA OMAO
LTJG Megan Nadeau	Mapping Watchstander	NOAA Corps
Lillian Stuart	Mapping Watchstander	NOAA OMAO

5. Mapping Statistics

Dates	19 May – 03 June 2010
Weather delays days	0
Total non-mapping days	0
Total survey mapping days	0
Total transit mapping days	14.6 days
Line kilometers of survey	6598.5 km
Average ship speed during multibeam collection	11.1 kts

6. Mapping Sonar Setup

The NOAA Ship *Okeanos Explorer* (EX) is equipped with a 30 kHz Kongsberg EM 302 multibeam sonar and a 3.5 kHz Knudsen sub-bottom profiler (SBP 3260). During this cruise EM 302 bottom bathymetric and backscatter data were collected.

The ship used a POS MV ver. 4 to record and correct the multibeam data for any vessel motion. C-NAV GPS system provided DGPS correctors with positional accuracy expected to be better than 2.0 m.

All corrections (motion, sound speed profile, sound speed at sonar head, draft, sensor offsets) are applied during real time data acquisition. The XBT casts (Deep Blue, max depth 760 m) were taken every 6 hours and/or as necessary to correct for sound speed. The XBT cast data were converted to SIS compliant format using NOAA Veloicpy. See Appendix A for a complete list of software used for data processing.

Prior to cruise EX1002 Leg 3, Kongsberg technician Gregg Juergens was onboard and replaced all 24 of the transmit boards (TX36) in the EM302 TRU. Kongsberg recently redesigned these boards, with the new version called TX36 LC. It as determined during EX1002 Leg 3 that the new boards appeared to have solved the sector dropout problems seen in the EM302 data after the February 2010 software upgrades. However, susceptibility to side lobe detection seemed to have increased, with railroad track artifacts experienced more frequently in all water depths, and especially in deeper water.

7. Data Acquisition Summary

Table 1 lists the transducer and attitude sensor offsets determined during the 2010 sea acceptance test (EX1001). The pitch attitude offset of -0.8 was increased from the previous value of -0.7 while Kongsberg technician Gregg Juergens was onboard during EX1002 Leg3. Apart from this change, the PU Parameters were setup to be identical to the 2009 survey season. For complete processing unit setup utilized for the cruise, please refer to Appendix C.

	Roll	Pitch	Heading
TX Transducer	0.0	0.0	359.98
RX Transducer	0.0	0.0	0.03
Attitude	0	-0.8	0.0

Table 1. Angular offsets for Transmit (TX) and Receive (TX) transducer and attitude sensor

Multibeam data was continuously collected during the entire transit from Honolulu to Guam. Interruptions in data continuity are due to built in system tests (BIST) periodically run on the multibeam system. These interruptions are the result of approximately 10 to 40 minutes of testing. All data is either within the US Exclusive Economic Zone or the high seas. All data will be archived with NGDC with individual metadata records. All raw and processed data products are in WGS84 format.

A note on time zone changes: all multibeam and associated data are time stamped with UTC time. The daily cruise log included this report gives details of when ship’s time was shifted for gradual time zone adjustment throughout the cruise.

8. Multibeam Data Quality Assessment and Data Processing

Data Quality Assessment

On May 22, the ship crossed Necker Ridge, which had been previously mapped during cruises EX0909 Legs 1 and 2. Although the azimuths of the lines from year to year were not perfectly perpendicular, a comparison was nonetheless made between the two datasets to examine the system’s data quality from year to year. In the area of data overlap, each dataset was gridded at a 50 m cell size in CARIS HIPS 6.1, and exported to ASCII xyz. Fledermaus v.6 sd objects were then created of each ASCII xyz. The sd objects were then compared using the surface difference functionality in Fledermaus (see Figure 3). The comparison showed excellent results, with an average difference of 7.5 meters and a standard deviation of 17.6 meters. The largest observed differences of up to 227.6 m were due to degraded data quality in the extreme outer beams, and due to horizontal positional offsets on very steep slopes. The comparison depths were from approximately 2600 to 5000 m.

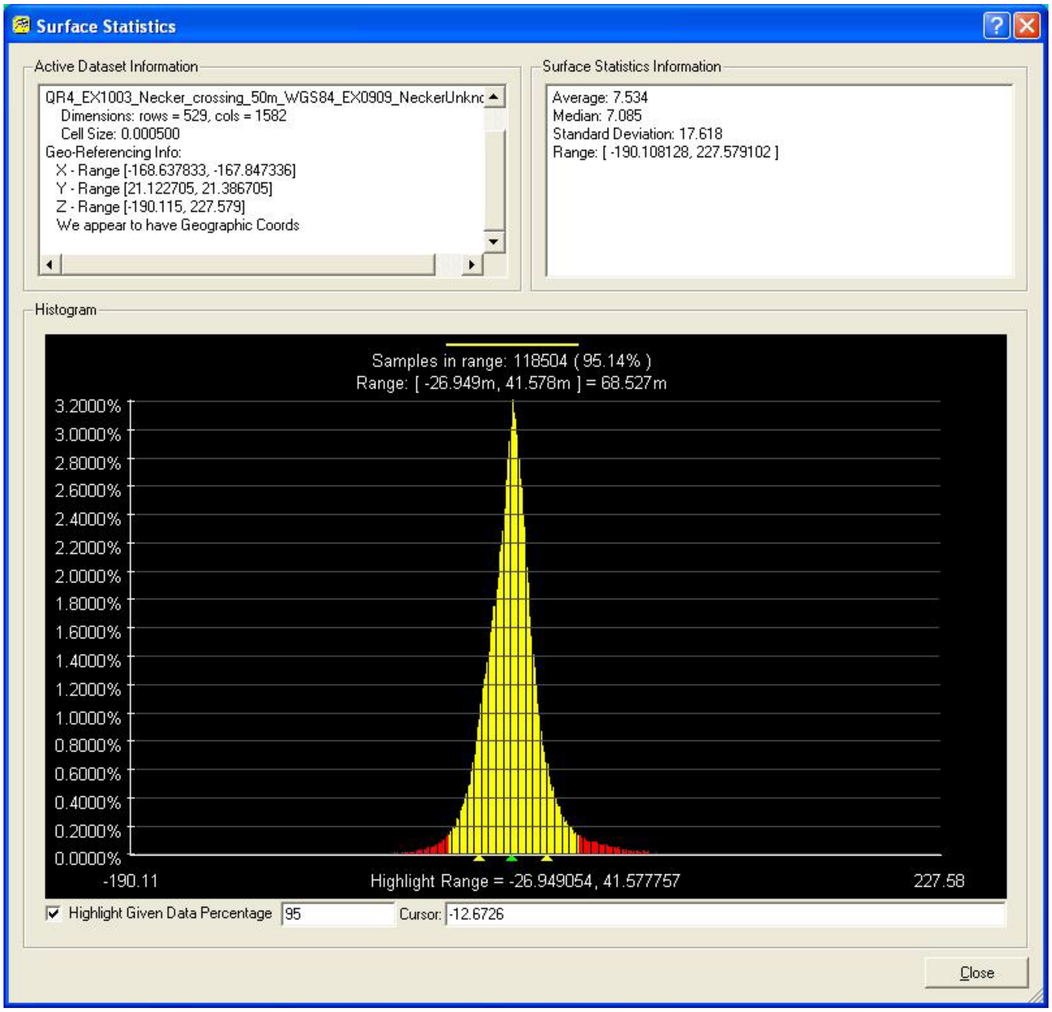


Figure 2. Statistical results of 2009 vs 2010 Necker Ridge multibeam data.

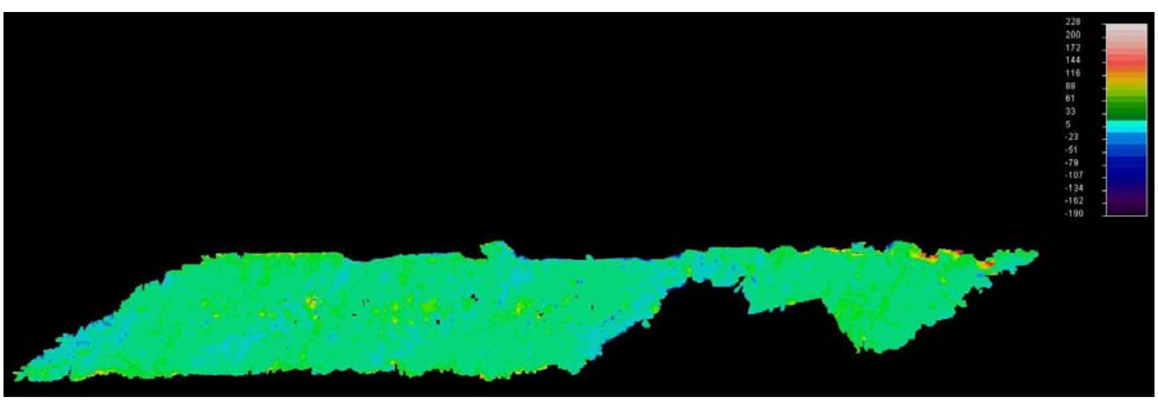


Figure 3. Difference surface comparing Necker Ridge data mapped by the Okeanos Explorer in 2009 and 2010.

On June 2, the ship crossed the Mariana Trench, which presented the opportunity to test the maximum depths to which the EM302 can obtain quality multibeam data. The system specifications state the EM302 can collected data down to depths of 7000 m, but actual maximum depth had not yet been tested. The results were that after examining and cleaning the raw data collected while transiting over the Mariana Trench, the deepest accurate depth recorded was 7954 m. A full report of the data is included in Appendix B of this report.

Additionally, the following data quality issues were evaluated during the cruise:

- Side lobe detection observed as severe rail road tracks in waters 2000 - 4000 m
- Apparent reduced swath coverage as compared to the 2009 field season
- Apparent increased susceptibility to environmental noise

Side lobe detection was observed after the TX36 boards in the EM302 were upgraded to the newer TX36 LC version, resulting in artifacts parallel to the ship track, resembling railroad tracks. These artifacts were observed to be up to approximately 200 m high, and were present in all water depths. The artifacts were most severe over deep (>4000 m) very flat terrain. It was determined that setting the along direction angle in SIS to negative values greatly reduced, and in most cases eliminated, the artifacts.

Initial impressions from experienced technicians onboard after the TX36 LC upgrade was that swath coverage had been greatly reduced, as compared to those experienced during the 2009 field season over similar seabed and water depth conditions, and environmental conditions. This was observed by Kongsberg Technician Gregg Juergens during EX1002 Leg 3. Swath coverage was observed to be as low as 1:1 coverage to water depth ratio, but also as high as 3:1, thus the results were inconsistent and therefore inconclusive. Swath coverage will continue to be monitored.

Apparent increased susceptibility to environmental noise was not tested due to the excellent weather conditions experienced throughout the cruise.

Data processing

All raw multibeam data was imported and cleaned in CARIS 6.1. Cleaned data was then exported to ascii xyz by line, resulting in a separate xyz file for each multibeam line collected. Data was also exported to ascii xyz after downsampling to 100 m grids. These downsampled xyz's were then used to generate Fledermaus v.6 *.sd objects. Each *.sd object was then exported to a georeferenced image (embedded geotiff). All data are in geographic WGS84 format. All raw and processed multibeam data products can be accessed via www.ngdc.noaa.gov.

9. Subbottom Profiler Sound Survey

A shipboard sound level survey was conducted while operating the Knudsen subbottom profiler in water depths from 500 to 1400 m during cruise EX1001. It was determined that further testing was required, and was planned for this cruise. However, time and other survey activities did not permit the necessary further testing. Further tests should be conducted as time is available during EX1004 Leg 4, EX1005 or EX1006.

10. Cruise Calendar

For a more detailed account of daily events, see *Daily Cruise Log (section 10).*

May 2010						
Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
	18 Lilian Stuart boards vessel	19 Took on fuel Commence transit to Guam 1530. MB data collection commenced approx 1730.	20 Continued transit to Guam	21 Continued transit to Guam. 20 minutes of speed vs. swath coverage testing conducted.	22 Continued transit to Guam	23 Continued transit to Guam
24 Continued transit to Guam. Crossed the international dateline at 1323 ship time (0023 UTC)	25 This date was lost when we crossed the dateline.	26 Continued transit to Guam	27 Continued transit to Guam	28 Continued transit to Guam	29 Continued transit to Guam	30 Continued transit to Guam
31 Continued transit to Guam						

June 2010						
Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**
	1 Continued transit to Guam. Time zone shift onboard: 0500 became 0400. Detected TX36 board #16 failure.	2 Continued transit to Guam. Crossed Mariana Trench.	3 Arrive Guam, USCG dock on Navy Base	4 Lobecker departs vessel		

11. Daily Cruise Log

ALL DATES AND TIMES IN SHIP TIME

19 May 2010

The ship took on fuel during the day, then departed fuel dock to begin transit to Guam at 1530 HST. Mapping team collected BISTs at fuel pier, and immediately upon departure from harbor. RX noise levels were normal for the pierside conditions. Collected multibeam data overnight with last year's SIS settings, almost everything in auto. Data quality very poor with side lobe detection in all depths > ~2000 m. Multibeam watches start tomorrow, so data quality is expected to improve with monitoring.

Multibeam TRU power malfunctioned while running a series of BIST around 2230. A TRU remote restart was required to get it up and running again. UPS records showed no spike or other anomalies in power at that time. Temperature of TRU closet was fine. Circuit breaker, cables, transformer in TRU closet were fine.

20 May 2010

Continued transit to Guam with continuous multibeam data collection. Data quality in ~4500 meters looked good with along direction angle set to 9 degrees. Swath coverage is barely making 1:1. In ~4500 m of water we are seeing swatch coverage 4.9 – 5 km. Seafloor appears to be very soft in the bottom backscatter.

BISTs all looked normal. TRU room temperature has been holding steady in the mid 70's Fahrenheit.

Conducted fire and abandon ship drills.

21 May 2010

Continued transit to Guam with continuous multibeam data collection. In the morning we transited over a harder bottom and a wider swath of up to 6000 m was observed. Still experiencing significant side lobe detection, as expected.

Weather was fair throughout the day with following seas 2-3 ft and winds 10-15 kts.

Adjusting filters reduced sidelobe detection immensely, starting around 1200 HST. Changing one filter setting, then putting it back to previous setting, appeared to "wake up" filter and its ability to reduce side lobe detection. Best data quality with along direction -6, forced into extra deep mode, medium-normal-medium, all filters on except aeration.

Coverage holding steady at ~5 km in 4500 m water with flat bottom at 11 kts in excellent survey weather.

Tested new spare XBT launcher – success. Will revert to using original launcher.

RX noise levels have all been in the high 40s / low 50s range so far. A new BIST spreadsheet has been created to track the vessel and environmental conditions present during each BIST, which will be easier in the long run than making descriptive titles for each BIST text file.

The data quality is looking decent, with these settings:

-the along direction set to -6
-forcing the ping mode to extra deep.
-spike filter set to strong
-range gate set to normal
-penetration filter to medium

We were able to conduct 20 minutes of speed testing today. At 11 knots we are getting about 1:1 swath ratio in 4700 meters water. At 8 knots we got a steady 6 km swath. Later in the trip after we get closer to Guam and the ship is more comfortable with getting there on time, we will be able to do more testing.

The internet continues to be slow, making communications with shore difficult.

We crossed over a section of Necker Ridge that was mapped by this ship during EX0909 Legs 1 and 2 last year. A comparison of last year's data to this year's data will be performed.

At 21.23N, 170.00W, the ship turned slightly south on a new heading of 266°.

22 May 2010
Continued transit to Guam with continuous multibeam data collection. Weather remained good survey weather, with following wind and seas. Winds 10-15 kts from 100° and waves less than 3 ft.

23 May 2010
Continued transit to Guam with continuous multibeam data collection. Getting 4.75 km to 5 km swath coverage in 5400 m of water over very flat and soft seafloor. Setting the along direction angle to a negative number has eliminated most of the side lobe detection rail road tracks. We are achieving the best data with these settings: Extra deep (forced) ping mode, along direction -4° to -6°, Equiangle beam spacing.

At 1822 switching to auto angular mode improved quality of edges of swath as we approached seamount and bottom type changed. Auto high density equidistant, with max angles 75/75 and max coverage 5000 m.

At 2053 UTC in 5400 m water over flat bottom, experimented with SIS settings: turned FM mode off, high density equidistant on, forced into extra deep. Swath coverage was wider but very sparse beams, bottom tracking horrible. Also tested effect of changing coverage angles (70, 60, 50, 30.) while in 5500 m water in extra deep.

24 May 2010
Continued transit to Guam with continuous multibeam data collection. Crossed the international dateline at 0023 UTC (1323 ship time) at 180E, 20.57N. Dateline ceremony was conducted on the bow.

Brought UTM60N geotiff of SnS data into Hypack UTM60N project. In IVS, reprojected geo sd to utm60N sd, exported image. Continued mapping on the way to Guam. Data quality is much improved. The survey team has figured out appropriate settings to eliminate railroad tracks and achieve wider swaths. It is important to note that data quality is improved due to shallower water (3000 m) and harder seafloor. The following SIS settings are in use: Ping mode: Auto – equiangle, deep mode, 3000 m, hard bottom, 7 km+ swath. Data quality and swath coverage are back to what we are accustomed to seeing.

25 May 2010
This date was lost when we crossed the date line

26 May 2010
Continued transit to Guam with continuous multibeam data collection. Indonesian science partner Cecep Sunya was trained on CARIS with sample EM302 files from this cruise.

Data quality remained high quality with minimal railroad tracks and excellent swath coverage. Weather was excellent for survey, with following seas of less than 4 ft and winds at 13 kts from 195°.

27 May 2010
Continued transit to Guam with continuous multibeam data collection. Continued Cecep's training in CARIS and Fledermaus with data from this cruise.
Weather was great in the morning with variable winds at 3-5 kts, a 4-5 ft swell.

Operational improvement to SIS and Hypack: we can now bring in background data into both software packages. Dxfs of bathy contours and geotiffs of bathy grids have been generated for both software. SIS versions are geographic in WGS84 format. Hypack versions are projected in appropriate UTM zones. All files were generated using Sandwell and Smith global bathymetry as source data, then processed in Fledermaus and AutoCAD.

Discussed with engineering department about the possible effects their normal activities could be having on our data quality in terms of increased noise. They are going to work up a spreadsheet of equipment that is running now while our data looks so good so that if a change in data quality is observed we can track if new equipment is running.

28 May 2010
Continued transit to Guam with continuous multibeam data collection. Weather is great for survey. Less than one foot chop on 4-6 ft swell. We will be transiting through flat deep area for the next couple of days.

29 May 2010
Continued transit to Guam with continuous multibeam data collection. Weather continues to be great for survey. Still less than one foot chop on a 4-6 ft swell. Continue transit through flat deep area.

30 May 2010
Continued transit to Guam with continuous multibeam data collection. Auto/ED mode in 5600 m soft bottom coverage of 4-5 km. Manual/EX mode in same exact conditions coverage 6 km +. This inconveniently coincided with a slightly harder bottom, so we need to continue testing.

Turned on the singlebeam now that we are in depths >5700 m. SVP extended to 988 m in Velocipy then to 12,000 m and thinned in SIS applied during EA600 acquisition. No interference with multibeam observed.

Speed testing in 5800 m water over extremely soft bottom for swath coverage. Speeds 10, 9, 8, 7, 6 were compared. Coverage even at 6 knots barely approached 5 km, but backscatter waterfall is so dark we can barely see it against the black background.

31 May 2010
Continued transit to Guam with continuous multibeam data collection. Getting 6-7 km swath coverage in 5950 m medium to hard bottom. Side lobe detection minimal with along direction set in -3 to -5 range.

01 June 2010
Continued transit to Guam with continuous multibeam data collection.

SHIP TIME ADJUSTMENT: Time zone adjustment was made, at 0500 ship time, the hour rolled back to 0400.

At 0840 local (2240 UTC) BIST was run for normal procedures. TX36 and TRU power test failed. Board 16 again. Bridge 1 test for board 16 is 1.9 volts, all others are 120-122 volts. This is the same problem slot as last year. Kongsberg has been notified.

Chief Engineer compared baseline engineering checklist to determine if any additional equipment was operated during the pinpointed 48 hour window that the board was determined to have failed (since the last successful BIST). Two minor operations:

1. The routine testing of the emergency generator for a couple of minutes right before the failed BIST. The timing is suspected to be coincidental.
2. Two fans in the winch room were turned on last night at some point. Neither of these events is suspected to be the cause of the board failure, as the emergency generator was not connected to ship's power when it was started up, and the fans are normally turned on/off as necessary.

The Chief Engineer also verified that all major engineering equipment on the ship has been operating normally. Also, as far as scheduled daily or weekly engineering activities go, does not seem like there are any.

Chief ET tested the power coming from extra socket on the back of the TRU and the power looked clean. We are collecting a datagram of the power for 24 hrs to observe a day's worth of power for regularity.

The XBT hand held launcher not working, so the spare was used. ETs are checking the connections.

At 1100, survey tech noticed regular spikes in data coverage, suspected due to singlebeam running. Is EM302 more susceptible to interference from the EA600 with a failed board?

The engineering department conducted 15 minutes of welding. No change in data quality was observed, although the data quality was already generally poor in a very soft bottom and +5800 m water depth.

The engineering department reminds that a thermal imaging camera is available for troubleshooting the multibeam, particularly slot 16.

Scott Hill from NCDDC is onboard for this cruise. Discussed with Scott possibilities for improving the geographic bounds of multibeam files in the metadata records. This is an ongoing discussion.

02 June 2010

Continued transit to Guam with continuous multibeam data collection, including transit over the Mariana Trench today. EM302 collected data to just under 8000 m then lost bottom detection all together. Singlebeam collected when we switched off the multibeam.

While approaching the Mariana Trench, various settings were tried to squeeze the deepest data out of the system. The best results were obtained with ping mode and angular coverage mode both set to auto. Data coming out of the other side of the Trench was poorer quality possibly due to the system taking a longer time to lock onto the bottom.

03 June 2010

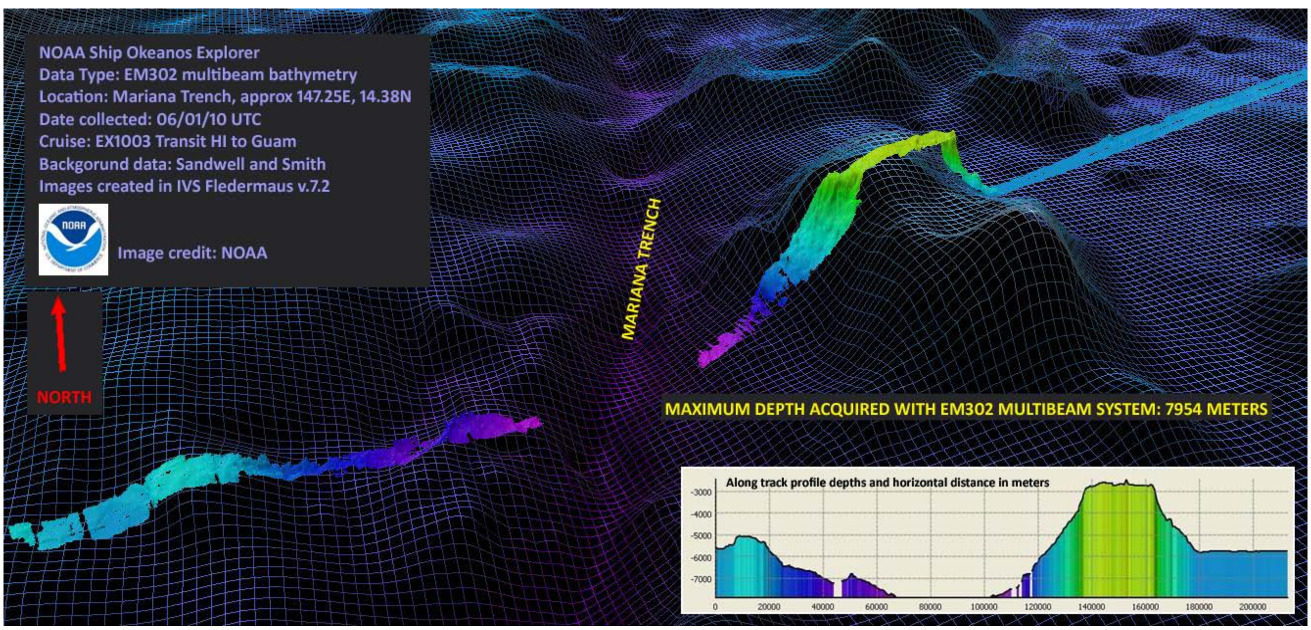
Multibeam secured at 0815. Came into port in the morning in Guam at US Coast Guard dock on Naval Base.

12. Appendices

Appendix A: Field Products

Mariana Trench Report

Mariana Trench EM302 Data
Multibeam data collected by the *Okeanos Explorer* on June 2, 2010
By Elaine Stuart
Overview
On June 2, 2010, during the transit from Hawaii to Guam (cruise EX1003), the *Okeanos Explorer* had the opportunity to see how deep the EM302 could perform while transiting over the Mariana Trench. The EM302 was able to achieve up to nearly 8000 m. The system specifications give the EM302 a depth range to 7000 m. The multibeam system was acquiring good data approximately up to the 8000 m mark, however SIS is hard-coded to accept a maximum depth of 8000 m in the Runtime Parameters so depths beyond this range could not be acquired. Environmental conditions were not a factor in data quality or collection, as conditions



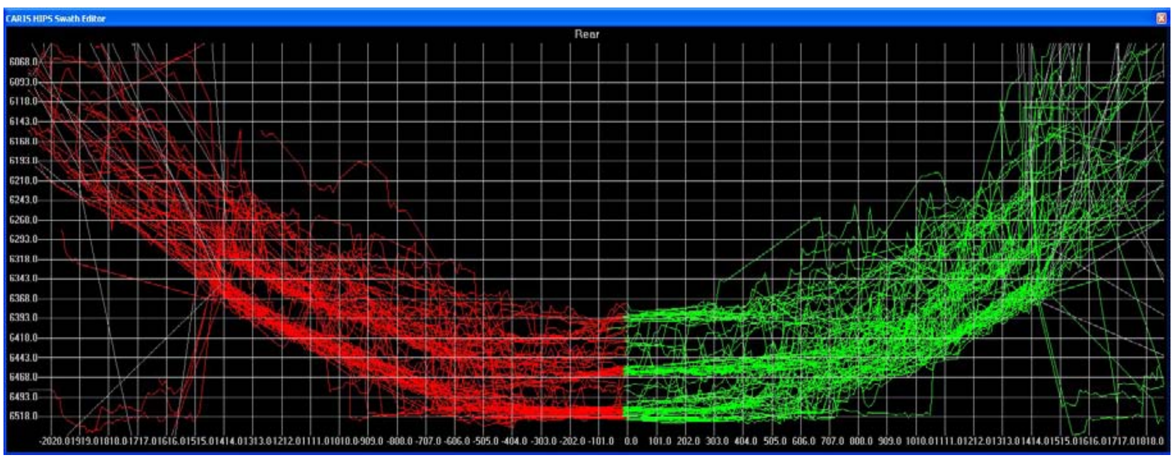
throughout this crossing were very mild with 2-4 ft swell and wind at 5-10 kts.

Figure 1: EM302 data collected over the Mariana Trench under laid with wireframe of Sandwell & Smith compiled data

Going Over The Mariana Trench
The SIS collection settings leading up to the Mariana Trench were generally in Manual Ping Mode/Extra Deep, with attempts made with different settings to improve and retain data quality (0000-0627—all times are Guam Local Time). These included changing Along Direction Pitch Angle from -5 to 0, applying different filters strengths, taking the maximum port/starboard

angles in from 70/70 to 35/35 to 20/20 to 15/15, decreasing ship's speed from 8.5 kts to 7 kts to 5 kts and popping into Auto Ping Mode for short periods of time to "wake up" the system. None of these changes had much effect and the data slowly degraded, and the system was put into Auto Ping mode at 0628. Following this, "Force Depth" was utilized multiple times and still could only find the bottom intermittently. By 0643, the EA600 was turned on and set to record. At 0653, XBT #51 was applied to the data. At 0656, the system locked onto the bottom and data was looking superb in 7589 m of water. It continued to collect excellent data until hitting the Sandwell & Smith 8000 m contour line, where the maximum depth of 8000 m was reached. This value could not be exceeded in the Runtime Parameters due to a hard coded maximum depth of 8000 m. At this point, the multibeam was secured until reaching approximately 8000 m water depth on the other side of the trench.

Once the ship had traveled into shallower waters of the Mariana Trench and was ascending up the western wall, pinging started again at 0947 with EA600 depths reading between 7800-7900 m. Since data had looked so good in Auto Ping mode before data collection was suspended, the system was restarted in Auto/Extra Deep, with Along Direction Pitch Angle set to zero and maximum angles set to 20/20. The system could not find the bottom consistently even after many "Force Depth" attempts. At 0954, Manual/Extra Deep mode was tried and data coming in improved so line number 71 was started. It is important to note that after this initial start, the data



quality never reached the condition seen leading up to the Mariana Trench. Again, many settings were tried from 1000-2215, including switching the ping mode was switched back and forth from Auto to Manual periodically, with no real improvement. The system's side lobe detection problem became much more pronounced on the transit out of the trench, with many pings at once becoming huge "smiles" covering the entire swath (see Figure 2). At best the data deteriorated into giant "rail road tracks" rising 250 m, where the outer beams and the data at nadir

Figure 2: Giant "smile" data from side lobe interference taken from Caris Swath Editor Rear View. This was in 6500 m, not too long after leaving the Mariana Trench, where the top of the smiles reached 6070 m.

were finding bottom, but data at an equidistant point on both sides were digitizing on the side lobes. This could have resulted from the penetration filter set to "strong" which causes the system to focus on anything above the seafloor in an effort not to digitize on anything below it. These issues are in contrast to the data collected on the other side of the trench, where the problem was more the system's inability to track the bottom. After 2215, railroad tracks had almost entirely disappeared, seemingly upon the ship reaching shallower depths of 2241 m. With the recent replacement of the RX boards in Hawaii, railroad tracks have generally only been seen in depths of 3000 m or more.

<u>Findings</u>

It is unknown why the data quality was worse traveling away from the Mariana Trench, and whether this was because the EM302 had to reestablish bottom detection after pinging was disabled at 8000 m, unlike when the ship was heading towards the trench and had already had been locked on the bottom for a while. The large "smiles" (and mega railroad tracks) that were observed on the transit leaving the trench had not been seen before or since. It has been noticed with this system that bottom type plays a significant role in data quality—where a hard bottom produces beautiful clean data, and a soft bottom tends to lead to patchy data quality and reduced coverage—the latter being consistent with system spec capabilities. With data collected right before the trench, one side was consistently holding the bottom better—in this case it was the starboard side—while after the trench, it was the port side. When this was the case, the seabed image in SIS would always show brighter backscatter data on that particular side—leading to the conclusion that better data quality was resulting from a harder seafloor. Yet there were some strange occurrences where changes in a brighter Seabed Image that called the validity of this into question. For example, the EA600 Single Beam system was turned on at one point heading away from the trench

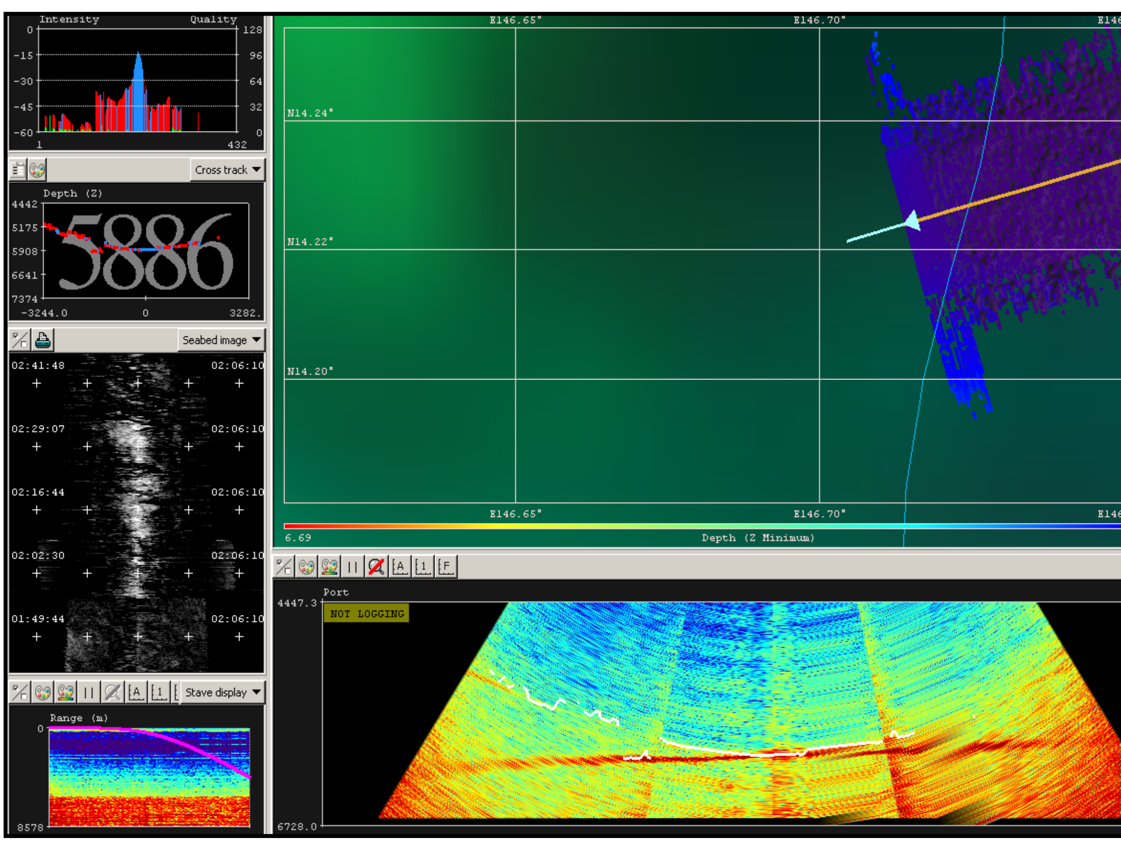


Figure 3: SIS acquisition screen showing Seabed Image brightening around nadir after the EA600 Single

Beam was started up until it was secured again.

and suddenly the Seabed Image looked brighter (see Figure 3), and as a consequence, the data improved. There is a secondary question here as well; can the single beam sometimes help the EM302 collect better data? There was possibly another example of this when the EM302 locked on the bottom in 7589 m (see above)—the EA600 had been turned on a few minutes before. Another example of the Seabed Image changing was a few days earlier around midnight on May 30th GMT, pinging and logging was suspended to do a BIST and after data collection was resumed, there was a bright moment in the Seabed Image data where the data looked better than it did before the pinging and logging was secured. After the flare, different settings were tried to see if this odd occurrence could be replicated. It was found that changing ping modes from Auto/Extra Deep to Manual/Extra Deep resulted in a brighter Seabed Image as well as better data (See Figure 4). Ping modes were switched from Auto and Manual to test this and a change in brightness in the Seabed Image was seen with every change back to Manual—but the brighter Seabed Image and improved data quality would never last and the Seabed Image would dull and with it, the data quality, eventually reverting back to its original poor state. It is possible that in both cases, a harder bottom coincided with the exact time when each change was made. Unfortunately since this was observed during a transit, we could not pass back over the same spot with different settings to verify the seafloor type or the effect (or non effect) on the Seabed Image. Also, the above occurrences are onetime events only seen when data quality is poor and the Seabed Image is very dark and indistinct—i.e. the Seabed Image is not affected every time the EA600 is turned on or the Ping mode is changed. One thing remains constant though, the brighter the Seabed Image, the better the data—the question is if this is always a product of the seabed characteristics.

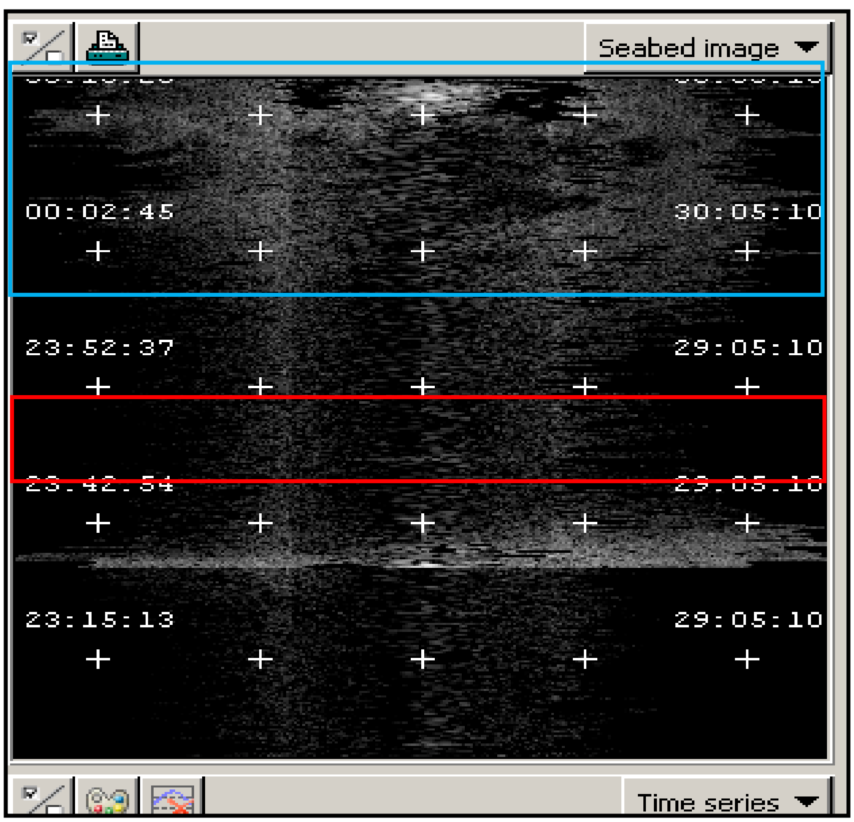


Figure 4: Seabed Image data from SIS in 5680 m showing brighter backscatter after a BIST (bracketed in red) and then after changing from Auto/Extra Deep to Manual/Extra Deep Ping modes (bracketed in blue).

Conclusions

Collecting EM302 data over the Mariana Trench was a little inconsistent as well as puzzling. The settings that worked effectively heading towards the Mariana Trench, had no effect once the ship resumed data collection. But even recognizing that there are inconsistencies is an important step. Unexplained sporadic occurrences or data anomalies seen for the first time shows that there are still things to learn about the system. Collecting data over the Mariana Trench gave us an excellent opportunity to put the system through its paces and get a chance to observe these results: 1) The system can operate to 8000 m and 2) There are no hard and fast rules that can be applied to each problem to improve data quality. As for results concerning Seabed Image, unaccounted for changes of brightness need to be documented in the future along with further testing—in order to understand Seabed Image acquisition in SIS concerning the EM302.

Appendix B: Tables of Files Collected during EX1003

EX1003 MB ACQUISITION LOG					
MB Line Filename	**SVP File Applied**	**Julian Day**	**Date (GMT)**	**SOG**	**HDG**
0000_20100520_023941_EX.all	XBT_052010_01_thinned.asvp	140	5/20/10	10.5	270
0002_20100520_054151_EX.all	XBT_052010_01_thinned.asvp	140	5/20/10	10.5	270
0003_20100520_091822_EX.all	XBT_052010_01_thinned.asvp	140	5/20/10	10.5	270
0004_20100520_151818_EX.all	XBT_052010_01_thinned.asvp XBT_052010_02_thinned.asvp	140	5/20/10	10	270
0005_20100520_211821_EX.all	XBT_052010_02_thinned.asvp	140	5/20/10	10	270
0006_20100520_235910_EX.all	XBT_052010_03_thinned.asvp	140	5/20/10	10	270
0007_20100521_055243_EX.all	XBT_052010_04_thinned.asvp	141	5/21/10	10	270
0008_20100521_060546_EX.all	XBT_052010_04_thinned.asvp	141	5/21/10	10	270
0009_20100521_120546_EX.all	XBT_052010_05_thinned.asvp XBT_052010_06_thinned.asvp	141	5/21/10	10	270
0010_20100521_180547_EX.all	XBT_052110_06_thinned.asvp XBT_052110_07_thinned.asvp	141	5/21/10	10.5	271
0011_20100522_000544_EX.all	XBT_052110_07_thinned.asvp	142	5/22/10	10.5	271
0012_20100522_004538_EX.all	XBT_052110_07_thinned.asvp	142	5/22/10	10	271
0013_20100522_022043_EX.all	XBT_052110_07_thinned.asvp	142	5/22/10	9	271
0014_20100522_022752_EX.all	XBT_052110_07_thinned.asvp	142	5/22/10	8	271
0015_20100522_023235_EX.all	XBT_052110_07_thinned.asvp XBT_052110_08_thinned.asvp	142	5/22/10	10.5	268
0016_20100522_083234_EX.all	XBT_052110_08_thinned.asvp XBT_052110_09_thinned.asvp	142	5/22/10	11	270
0017_20100522_143237_EX.all	XBT_052110_09_thinned.asvp XBT_052110_10_thinned.asvp	142	5/22/10	10.5	270
0018_20100522_203232_EX.all	XBT_052110_10_thinned.asvp XBT_052110_11_thinned.asvp	142	5/22/10	10.5	270

0019_20100523_000111_EX.all	XBT_052210_11_thinned.asvp XBT_052210_12_thinned.asvp	143	5/23/10	10	264
0020_20100523_060110_EX.all	XBT_052310_12_thinned.asvp XBT_052310_13_thinned.asvp	143	5/23/10	10	265
0021_20100523_120114_EX.all	XBT_052310_13_thinned.asvp XBT_052310_14_thinned.asvp	143	5/23/10	10.5	266
0022_20100523_180113_EX.all	XBT_052310_14_thinned.asvp	143	5/23/10	10.5	268
0023_20100523_202323_EX.all	XBT_052310_14_thinned.asvp XBT_052310_15_thinned.asvp	143	5/23/10	10.5	266
0024_20100524_002738_EX.all	XBT_052310_15_thinned.asvp	144	5/24/10	10.5	266
0025_20100524_015145_EX.all	XBT_052410_15_thinned.asvp	144	5/24/10	10.5	266
0026_20100524_020208_EX.all	XBT_052410_15_thinned.asvp XBT_052410_16_thinned.asvp	144	5/24/10	10.5	266
0027_20100524_080203_EX.all	XBT_052410_16_thinned.asvp XBT_052410_17_thinned.asvp	144	5/24/10	11	266
0028_20100524_140206_EX.all	XBT_052410_17_thinned.asvp XBT_052410_18_thinned.asvp	144	5/24/10	11	264
0029_20100524_200205_EX.all	XBT_052410_18_thinned.asvp XBT_052410_19_thinned.asvp	144	5/24/10	10	264
0030_20100525_003858_EX.all	XBT_052410_19_thinned.asvp	145	5/25/10	10	262
0031_20100525_011337_EX.all	XBT_052510_19_thinned.asvp XBT_052510_20_thinned.asvp	145	5/25/10	10	264
0032_20100525_071340_EX.all	XBT_052510_20_thinned.asvp XBT_052510_21_thinned.asvp	145	5/25/10	10	263
0033_20100525_131340_EX.all	XBT_052510_21_thinned.asvp	145	5/25/10	10	256
0034_20100525_191336_EX.all	XBT_052510_21_thinned.asvp XBT_052510_22_thinned.asvp	145	5/25/10	10.5	260
0035_20100526_000007_EX.all	XBT_052510_23_thinned.asvp XBT_052610_24_thinned.asvp	146	5/26/10	9.5	260
0036_20100526_000007_EX.all	XBT_052610_24_thinned.asvp XBT_052610_25_thinned.asvp	146	5/26/10	9	260
0037_20100526_121616_EX.all	XBT_052610_25_thinned.asvp	146	5/26/10	9	261
0038_20100526_181624_EX.all	XBT_052610_26_thinned.asvp	146	5/26/10	8.0	263
0039_20100526_194212_EX.all	XBT_052610_26_thinned.asvp	146	5/26/10	8.0	263
0040_20100526_200312_EX.all	XBT_052610_26_thinned.asvp	146	5/26/10	8.5	263
0041_20100527_000436_EX.all	XBT_052610_27_thinned.asvp	147	5/27/10	8.5	263

0042_20100527_013410_EX.all	XBT_052710_27_thinned.asvp XBT_052710_28_thinned.asvp	147	5/27/10	11	260
0043_20100527_073405_EX.all	XBT_052710_28_thinned.asvp XBT_052710_29_thinned.asvp	147	5/27/10	11	260
0044_20100527_133404_EX.all	XBT_052710_29_thinned.asvp XBT_052710_30_thinned.asvp	147	5/27/10	11	257
0045_20100527_193407_EX.all	XBT_052710_30_thinned.asvp	147	5/27/10	11	262
0046_20100528_000004_EX.all	XBT_052710_31_thinned.asvp	148	5/28/10	10.5	264
0047_20100528_023818_EX.all	XBT_052710_31_thinned.asvp XBT_052810_32_thinned.asvp	148	5/28/10	10.5	257
0048_20100528_083616_EX.all	XBT_052810_32_thinned.asvp XBT_052810_34_thinned.asvp	148	5/28/10	10.5	260
0049_20100528_143819_EX.all	XBT_052810_34_thinned.asvp XBT_052810_35_thinned.asvp	148	5/28/10	10	262
0050_20100528_203814_EX.all	XBT_052810_35_thinned.asvp	148	5/28/10	10	256
0051_20100529_000009_EX.all	XBT_052810_35_thinned.asvp	149	5/29/10	10	257
0052_20100529_050355_EX.all	XBT_052910_36_thinned.asvp XBT_052810_37_thinned.asvp	149	5/29/10	11	262
0053_20100529_110357_EX.all	XBT_052910_37_thinned.asvp XBT_052910_38_thinned.asvp	149	5/29/10	11	260
0054_20100529_170355_EX.all	XBT_052910_38_thinned.asvp XBT_052910_39_thinned.asvp	149	5/29/10	10.5	256
0055_20100529_230353_EX.all	XBT_052910_39_thinned.asvp	149	5/29/10	10.5	256
0056_20100529_234033_EX.all	XBT_052910_39_thinned.asvp	149	5/29/10	10.5	253
0057_20100530_000334_EX.all	XBT_052910_39_thinned.asvp XBT_052910_40_thinned.asvp	150	5/30/10	10.6	254
0058_20100530_060332_EX.all	XBT_052910_40_thinned.asvp	150	5/30/10	10.7	255
0059_20100530_064417_EX.all	XBT_052910_40_thinned.asvp XBT_052910_41_thinned.asvp	150	5/30/10	10.8	256
0060_20100530_064417_EX.all	XBT_052910_41_thinned.asvp	150	5/30/10	10.9	256
0061_20100530_125848_EX.all	XBT_052910_42_thinned.asvp	150	5/30/10	11	256
0062_20100530_185849_EX.all	XBT_052910_42_thinned.asvp XBT_052910_43_thinned.asvp	150	5/30/10	10.5	256

0063_20100531_000449_EX.all	XBT_053110_43_thinned.asvp XBT_053110_44_thinned.asvp	151	5/31/10	10.3	253
0064_20100531_060449_EX.all	XBT_053110_44_thinned.asvp XBT_053110_45_thinned.asvp	151	5/31/10	10.3	254
0064_20100531_060449_EX.all	XBT_053110_45_thinned.asvp XBT_053110_46_thinned.asvp	151	5/31/10	10.5	255
0065_20100531_120453_EX.all	XBT_053110_46_thinned.asvp	151	5/31/10	10.5	254
0066_20100531_180451_EX.all	XBT_053110_47_thinned.asvp	151	5/31/10	11	254
0067_20100601_002311_EX.all	XBT_060110_47_thinned.asvp XBT_060110_48_thinned.asvp	152	6/01/10	10.5	255
0068_20100601_062304_EX.all	XBT_060110_48_thinned.asvp XBT_060110_49_thinned.asvp	152	6/01/10	10.6	256
0069_20100601_122308_EX.all	XBT_060110_49_thinned.asvp XBT_060110_50_thinned.asvp	152	6/01/10	10.3	254
0070_20100601_182306_EX.all	XBT_060110_50_thinned.asvp XBT_060110_51_thinned.asvp	152	6/01/10	8.4	251
0071_20100601_235415_EX.all	XBT_060210_52_thinned.asvp	153	6/02/10	8.5	252
0072_20100602_041557_EX.all	XBT_060210_52_thinned.asvp	153	6/02/10	9.0	252
0073_20100602_045924_EX.all	XBT_060210_52_thinned.asvp XBT_060210_53_thinned.asvp	153	6/02/11	8.0	250
0077_20100602_125934_EX.all	XBT_060210_53_thinned.asvp XBT_060210_54_thinned.asvp	153	6/02/10	6.5	250
0078_20100602_185933_EX.all	XBT_060210_54_thinned.asvp	153	6/02/10	6.5	250

EX1003 SVP FILE LOG			
DATE (GMT)	**TIME (GMT)**	**XBT/CTD FILE NAME**	**LAT/LONG (WGS84)**
5/20/2010	4:16:56	XBT_052010_01	21 14.51147N 158 15.2959W
5/20/2010	18:27:59	XBT_052010_02	21 17.17383N 160 54.40332W
5/20/2010	22:37:37	XBT_052010_03	21 16.89282N 161 39.08789W
5/21/2010	4:14:44	XBT_052110_04	21 16.4836N 162 41.1875W
5/21/2010	10:11:43	XBT_052110_05	21 16.0932N 163 45.15273W

5/21/2010	16:05:38	XBT_052110_06	21 15.66382N 164 51.67188W
5/21/2010	22:41:53	XBT_052110_07	21 15.16553N 166 10.44336W
5/22/2010	4:08:35	XBT_052210_08	21 14.7605N 167 14.59961W
5/22/2010	10:02:04	XBT_052210_09	21 14.3352N 168 20.98047W
5/22/2010	16:02:21	XBT_052210_10	21 13.8904N 169 39.4863W
5/22/2010	22:34:54	XBT_052210_11	21 10.52173N 170 48.74219W
5/23/2010	4:04:25	XBT_052310_12	21 6.35718N 171 52.08984W
5/23/2010	10:06:12	XBT_052310_13	21 2.05835N 172 57.84375W
5/23/2010	16:07:40	XBT_052310_14	20 57.93677N 174 0.42969W
5/23/2010	22:41:04	XBT_052310_15	20 53.34497N 175 10.4707W
5/24/2010	4:27:39	XBT_052410_16	20 49.3213N 176 11.5820W
5/24/2010	10:05:28	XBT_052410_17	20 44.9825N 177 17.619W
5/24/2010	17:06:35	XBT_052410_18	20 39.6925N 178 38.0332W
5/24/2010	23:35:17	XBT_052410_19	20 34.86426N 179 51.72461W
5/25/2010	5:47:10	XBT_052510_20	20 27.33667N 179 3.9394E
5/25/2010	11:08:06	XBT_052510_21	20 20.1476N 178 6.1172E
5/25/2010	17:00	XBT_052510_22	20 11.9861N 177 00.1615E
5/25/2010	23:37:20	XBT_052510_23	20 7.30103N 175 56.28906E
5/26/2010	5:41:00	XBT_052610_24	19 57.2677N 175 2.18945E
5/26/2010	11:05:29	XBT_052610_25	19 50.8954N 174 11.0957E
5/26/2010	18:03:41	XBT_052610_26	19 42.83423N 173 6.48828E
5/27/2010	0:39:36	XBT_052610_27	19 34.85425N 172 2.61523E
5/27/2010	6:10:52	XBT_052710_28	19 27.84167N 171 6.42383E
5/27/2010	12:13:05	XBT_052710_29	19 19.2661N 169 58.5332E
5/27/2010	17:58:13	XBT_052710_30	19 7.5317N 168 53.8652W
5/28/2010	0:36:17	XBT_052710_31	18 54.19202N 167 40.3457E
5/28/2010	6:04:30	XBT_052810_32	18 45.53198N 166 52.72266E

5/28/2010	13:09:26	XBT_052810_34	18 3106180N 165 36.2734E
5/28/2010	19:06:43	XBT_052810_35	18 19.8514N 164 31.6894W
5/29/2010	1:41:59	XBT_052910_36	18 7.57446N 163 24.39844E
5/29/2010	7:08:18	XBT_052910_37	17 57.53748N 162 29.49121E
5/29/2010	13:03:19	XBT_052910_38	17 45.9729N 161 26.1240E
5/29/2010	19:03:33	XBT_052910_39	17 34.1581N 160 21.6621E
5/30/2010	1:37:06	XBT_053010_40	17 18.56165N 159 10.66504E
5/30/2010	7:04:42	XBT_053010_41	17 491406N 158 12.91309E
5/30/2010	13:03:01	XBT_053010_42	16 50.0242N 157 9.94434E
5/30/2010	19:06:12	XBT_053010_43	16 34.2856N 156 3.44902E
5/31/2010	1:33:50	XBT_053110_44	16 17.81445N 154 54.10547E
5/31/2010	7:24:32	XBT_053110_45	16 3.5544N 153 54.02734E
5/31/2010	13:04:05	XBT_053110_46	15 49.6973N 152 55.7178E
5/31/2010	20:06:17	XBT_053110_47	15 31.9690N 151 41.2724E
6/1/2010	2:49:15	XBT_060110_48	15 14.7019N 150 28.87793E
6/1/2010	8:19:52	XBT_060110_49	15 0.51868N 149 33.51465E
6/1/2010	14:06:13	XBT_060110_50	14 43.71658N 148 32.5049E
6/1/2010	20:01:57	XBT_060110_51	14 27.5117N 147 33.7744E
6/2/2010	2:34:58	XBT_060210_52	14 13.94177N 146 44.63867E
6/2/2010	8:28:29	XBT_060210_53	14 0.00989N 145 54.24316E
6/2/2010	14:09:06	XBT_060210_54	13 47.0647N 145 7.44824E

Appendix C: List of acronyms

BIST – Built In System Test

CIMS – Cruise Information Management System

CO – Commanding Officer

CTD – conductivity temperature and depth

CW – continuous wave

dB – decibels

DGPS –Differential Global Positioning System

DTM – digital terrain model

ECS – Extended Continental Shelf

ET – Electronics Technician

EX – NOAA Ship *Okeanos Explorer*

FM – frequency modulation

Ft – feet / foot

FOO – Field Operations Officer

kHz - kilohertz

Km – kilometers

KM – Kongsberg Maritime AS

Kt(s) – knots

LT – lieutenant

LTJG – lieutenant junior grade

M – meter / meters

Ma – megaannum

MBES – multibeam echosounder

NCDDC – National Coastal Data Development Center

NGDC – National Geophysical Data Center

NOAA – National Oceanic and Atmospheric Administration

NODC – National Oceanographic Data Center

OER – Office of Ocean Exploration and Research

OMAO – Office of Marine and Aviation Operations

PS – physical scientist

ROV – Remotely Operated Vehicle

SIS – Seafloor Information System

SST – Senior Survey Technician

SV – sound velocity

TRU – transmit and receive unit

TSG - thermosalinograph

UNCLOS – United Nations Convention on the Law of the Sea

UNH-CCOM/JHC – University of New Hampshire Center for Coastal and Ocean Mapping / Joint Hydrographic Center

UPS – uninterruptable power supply

US EEZ – United States Exclusive Economic Zone

USBL – ultra-short base line

WD – water depth

XBT – expendable bathythermograph

Appendix D: EM302 description and operational specs

EM 302 : Ideal for Ocean Exploration

There are several features of the Okeanos Explorer's 30 kHz multibeam that make it an excellent tool for ocean exploration. The following is a brief description of these features.

Depth Range

The system is designed to map the seafloor in water depths of 10 to 7000 meters. This leaves only the deepest parts of the deeper ocean trenches out of the EM 302's reach. Moreover, operational experience on the *Okeanos Explorer* has shown consistent EM 302 bottom detection at depth ranges in excess of 8000m.

High Density Data

In multibeam data, the denser the data, the finer resolution maps you can produce. The system can operate in dual swath, or multiping mode, which results in increased along track data density. This is achieved by detecting two swaths per ping cycle, resulting in up to 864 beams per ping.

The Okeanos Explorer mapping team typically operates the multibeam in high density equidistant ping mode, which results in up to 864 soundings on the seafloor per ping.

Full Suite of Data Types Collected

The system collects seafloor backscatter data, which provides information about the character of the seafloor in terms of bottom type.

The system also collects water column backscatter data, which has the ability to detect gaseous plumes in the water column. The full value of this feature is still being realized.

FM chirp mode is utilized in water depths greater than 1000 meters, and allows for the detection of the bottom further out from nadir than with previous 30 kHz systems.

Multibeam Primer

The area of the seafloor covered, or ensonified, by a single beam within a pulse of sound, or ping, is called the beam footprint. This beam footprint is defined in terms of the across track and along track values. Both of these values are dependent on water depth and the beam width at which the sound pulse is transmitted and received. The across track beam width value is also dependent on the receive angle, or "listening" angle, of the system, and the angle from nadir which it is received from. The receive angle for the receive transducer on the Okeanos Explorer EM302 is 1°, which is the smallest possible angle currently available for the EM302 system. The further out from nadir a sounding occurs, the larger the footprint will be. For example, as seen in Table 1 below, in 2000 meters of water, a beam footprint will have a radius of 18 meters at nadir but 25 meters by the time it hits the seafloor at an angle 140 degrees out from nadir.

Calculated acrosstrack acoustic beam footprint for EM 302 (high density ping mode, 432 soundings/profile)				
Water depth (m)	**Angle from nadir**			
50	1 deg RX center	90 deg	120 deg	140 deg
100	1	0.5	1	1
200	2	1	2	3
400	4	2	3	5
1000	7	4	6	10
2000	18	9	16	25
4000	35	19	32	-
6000	70	37	-	-
7000	105	56	-	-

Table 1. Calculated across track EM 302 beam footprint. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Calculated acrosstrack sounding density for EM 302 (high density ping mode, 432 soundings/profile)			
Water depth (m)	**Swath Width**		
50	90 deg	120 deg	140 deg
100	0.2	0.4	0.9
200	0.5	0.8	1.7
400	0.9	1.6	3.5
1000	1.9	3.2	6.9
2000	4.6	8.1	17.4
4000	9.3	16.2	-

Table 2. Calculated across track EM 302 sounding density. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 17.

Acrosstrack sounding density describes the spacing between individual soundings on the seafloor in the acrosstrack direction. The maximum swath of the EM 302 is 150 degrees. At this swath, the sounding density will be the least dense, since the beams will be spread out over a larger horizontal distance over the seafloor. As the swath angle (width) is decreased, the sounding density will increase, as the same number of beams are now spread out over a smaller horizontal distance over the seafloor.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, one profile per ping					
			Alongtrack distance between profiles (m)		
Water depth (m)	**Swath Width (m)**	**Ping Rate (pings/second)**	**@4 kts**	**@8 kts**	**@12 kts**
50	275	3.2	0.7	1.2	1.9
100	550	1.8	1.1	2.2	3.3
200	1100	1	2.1	4.2	6.3
400	2200	0.5	4.1	8.2	12.2
1000	5500	0.2	10	20	30
2000	8000	0.1	15.2	30.5	45.7
4000	8000	0.06	19.2	38.5	57.7
6000	8000	0.04	24.5	49	73.4

Table 3. Calculated ping rate and along track EM 302 sounding density, one profile per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Calculated ping rate and alongtrack resolution for EM 302					
140 deg swath, two profiles per ping					
Water depth (m)	**Swath Width (m)**	**Ping Rate**	**Alongtrack distance between profiles (m)**		
			@4 kts	**@8 kts**	**@12 kts**
50	275	3.2	0.3	0.6	0.9
100	550	1.8	0.6	1.1	1.7
200	1100	1	1.1	2.1	3.2
400	2200	0.5	2	4.1	6.1
1000	5500	0.2	5	10	15
2000	8000	0.1	7.6	15.2	22.8

Table 4. Calculated ping rate and along track EM 302 sounding density, two profiles per ping. Reference: Kongsberg Product description, Kongsberg document 302675 Rev B, Date 14/06/06, p. 15.

Reference: Kongsberg Product Description: EM 302 multibeam echosounder

Appendix E: EM302 PU Parameters in use during EX1003

#// Database Parameters

#// Seafloor Information System
#// Kongsberg Maritime AS
#// Saved: 2010.02.11 00:29:52

#// Build info:
#* SIS: [Version: 3.6.1, Build: 174, DBVersion 16.0 CD generated: Tue Nov 11 15:39:05 2008]
[Fox ver = 1.6.29]
[db ver = 16, proc = 16.0]
[OTL = 4.0.-95]
[ACE ver = 5.5]
[Coin ver = 2.4.4]
[Simage ver = 1.6.2a]
[Dime ver = DIME v0.9]
[STLPort ver = 513]
[FreeType ver = 2.1.9]
[TIFF ver = 3.8.2]
[GeoTIFF ver = 1230]
[GridEngine ver = 2.3.0]

#* Language [3] #// Current language, 1-Norwegian, 2-German,3-English, 4-Spanish

#* Type [302]
#* Serial no. [101]
#* Number of heads [2]
#* System descriptor [50331648] #// 03000000

#// ***
#// Installation parameters

#{ Input Setup #// All Input setup parameters

#{ COM1 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [9600]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [0]
#* GGK [1] [0]
#* GGA [1] [1]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [1] [1]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM1

#{ COM2 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [19200]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [1] [1]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM2

#{ COM3 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [4800]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [1] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [1]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM3

#{ COM4 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#* Baud rate: [9600]
#* Data bits [8]
#* Stop bits: [1]
#* Parity: [NONE]
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} COM4

#{ UDP2 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [1] [1]
#* GGK [1] [0]
#* GGA [1] [0]
#* GGA_RTK [1] [0]
#* SIMRAD90 [1] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [1] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP2

#{ UDP3 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP3

#{ UDP4 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [1]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [1] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [1] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [1] [0]
#* DBT Depth [1] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [1] [0]
#* Height, special purp [1] [0]
#* Ethernet AttVel [0] [0]
#} Input Formats

#} UDP4

#{ UDP5 #// Link settings.

#{ Com. settings #// Serial line parameter settings.
#// N/A
#} Com. settings

#{ Position #// Position input settings.
#* None [0] [0]
#* GGK [0] [0]
#* GGA [0] [0]
#* GGA_RTK [0] [0]
#* SIMRAD90 [0] [0]
#} Position

#{ Input Formats #// Format input settings.
#* Attitude [0] [0]
#* MK39 Mod2 Attitude, [0] [0]
#* ZDA Clock [0] [0]
#* HDT Heading [0] [0]
#* SKR82 Heading [0] [0]
#* DBS Depth [0] [0]
#* DBT Depth [0] [0]
#* EA500 Depth [0] [0]
#* ROV. depth [0] [0]
#* Height, special purp [0] [0]
#* Ethernet AttVel [1] [1]
#} Input Formats

#{ Attitude Velocity settings #// Only relevant for UDP5 on EM122, EM302 and EM710, currently
#* Attitude 1 [1] [1]
#* Attitude 2 [1] [0]
#* Use Ethernet 2 [1] [1]
#* Port: [5602]
#* IP addr.: [192.168.2.20]
#* Net mask: [255.255.255.0]
#} Attitude Velocity settings

#} UDP5

#{ Misc. #// Misc. input settings.
#* External Trigger [1] [0]
#} Misc.

#} Input Setup

#{ Output Setup #// All Output setup parameters

#* PU broadcast enable [1] [1]
#* Log watercolumn to s [1] [1]

#{ Host UDP1 #// Host UDP1 Port: 16100

#{ Datagram subscription #//
#* Depth [0] [0]
#* Raw range and beam a [0] [0]
#* Seabed Image [0] [0]
#* Central Beams [0] [0]
#* Position [0] [0]
#* Attitude [0] [0]
#* Heading [0] [0]
#* Height [0] [0]
#* Clock [0] [0]
#* Single beam echosoun [0] [0]
#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [1]
#* Installation Paramet [0] [1]
#* BIST Reply [0] [1]
#* Status parameters [0] [1]
#* PU Broadcast [0] [0]
#* Stave Display [0] [0]
#* Water Column [0] [0]
#* Internal, Range Data [0] [0]
#* Internal, Scope Data [0] [0]
#} Datagram subscription

#} Host UDP1

#{ Host UDP2 #// Host UDP2 Port: 16101

#{ Datagram subscription #//
#* Depth [1] [1]
#* Raw range and beam a [1] [1]
#* Seabed Image [1] [1]
#* Central Beams [1] [0]
#* Position [1] [1]
#* Attitude [1] [1]
#* Heading [1] [1]
#* Height [1] [1]
#* Clock [1] [1]
#* Single beam echosoun [1] [1]

#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [1]
#* Installation Paramet [0] [1]
#* BIST Reply [1] [1]
#* Status parameters [0] [1]
#* PU Broadcast [1] [0]
#* Stave Display [0] [1]
#* Water Column [0] [1]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Host UDP2

#{ Host UDP3 #// Host UDP3 Port: 16102

#{ Datagram subscription #//
#* Depth [0] [1]
#* Raw range and beam a [0] [0]
#* Seabed Image [0] [0]
#* Central Beams [0] [0]
#* Position [0] [0]
#* Attitude [0] [1]
#* Heading [0] [0]
#* Height [0] [1]
#* Clock [0] [0]
#* Single beam echosoun [0] [1]
#* Sound Speed Profile [0] [1]
#* Runtime Parameters [0] [0]
#* Installation Paramet [0] [1]
#* BIST Reply [0] [0]
#* Status parameters [0] [0]
#* PU Broadcast [0] [0]
#* Stave Display [0] [0]
#* Water Column [0] [0]
#* Internal, Range Data [0] [0]
#* Internal, Scope Data [0] [1]
#} Datagram subscription

#} Host UDP3

#{ Host UDP4 #// Host UDP4 Port 16103

#{ Datagram subscription #//
#* Depth [1] [0]
#* Raw range and beam a [1] [0]
#* Seabed Image [1] [0]
#* Central Beams [1] [0]
#* Position [1] [0]
#* Attitude [1] [0]
#* Heading [1] [0]
#* Height [1] [0]
#* Clock [1] [0]
#* Single beam echosoun [1] [0]
#* Sound Speed Profile [1] [0]
#* Runtime Parameters [1] [0]
#* Installation Paramet [1] [0]
#* BIST Reply [1] [0]
#* Status parameters [1] [0]
#* PU Broadcast [1] [0]
#* Stave Display [1] [0]
#* Water Column [1] [0]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Host UDP4

#{ Watercolumn #// Host UDP4 Port 16103

#{ Datagram subscription #//
#* Depth [1] [0]
#* Raw range and beam a [1] [0]
#* Seabed Image [1] [0]
#* Central Beams [1] [0]
#* Position [1] [0]
#* Attitude [1] [0]
#* Heading [1] [0]
#* Height [1] [0]
#* Clock [1] [0]
#* Single beam echosoun [1] [0]
#* Sound Speed Profile [1] [0]
#* Runtime Parameters [1] [0]
#* Installation Paramet [1] [0]
#* BIST Reply [1] [0]
#* Status parameters [1] [0]
#* PU Broadcast [1] [0]
#* Stave Display [1] [0]
#* Water Column [1] [1]
#* Internal, Range Data [1] [0]
#* Internal, Scope Data [1] [0]
#} Datagram subscription

#} Watercolumn

#} Output Setup

#{ Clock Setup #// All Clock setup parameters

#{ Clock #// All clock settings.
#* Source: [1] #// External ZDA Clock
#* 1PPS Clock Synch. [1] [1]
#* Offset (sec.): [0]
#} Clock

#} Clock Setup

#{ Settings #// Sensor setup parameters

#{ Positioning System Settings #// Position related settings.

#{ COM1 #// Positioning System Ports:
#* P1T [1] #// Datagram
#* P1M [0] #// Enable position motion correction
#* P1D [0.000] #// Position delay (sec.):
#* P1G [WGS84] #// Datum:
#* P1Q [1] #// Enable
#* Pos. qual. indicator [] #//
#} COM1

#} Positioning System Settings

#{ Motion Sensor Settings #// Motion related settings.

#{ COM2 #// Motion Sensor Ports:
#* MRP [RP] #// Rotation (POSMV/MRU)
#* MSD [0] #// Motion Delay (msec.):
#* MAS [1.00] #// Motion Sensor Roll Scaling:
#} COM2

#} Motion Sensor Settings

#{ Active Sensors #//
#* APS [0] [COM1] #// Position:
#* ARO [2] [COM2] #// Motion:
#* AHE [2] [COM2] #// Motion:
#* AHS [3] [COM3] #// Heading:
#} Active Sensors

#} Settings

#{ Locations #// All location parameters

#{ Location offset (m) #//

#{ Pos, COM1: #//
#* P1X [0.00] #// Forward (X)
#* P1Y [0.00] #// Starboard (Y)
#* P1Z [0.00] #// Downward (Z)
#} Pos, COM1:

#{ Pos, COM3: #//
#* P2X [0.00] #// Forward (X)
#* P2Y [0.00] #// Starboard (Y)
#* P2Z [0.00] #// Downward (Z)
#} Pos, COM3:

#{ Pos, COM4/UDP2: #//
#* P3X [0.00] #// Forward (X)
#* P3Y [0.00] #// Starboard (Y)
#* P3Z [0.00] #// Downward (Z)
#} Pos, COM4/UDP2:

#{ TX Transducer: #//
#* S1X [6.147] #// Forward (X)
#* S1Y [1.822] #// Starboard (Y)

#* S1Z [6.796] #// Downward (Z)
#} TX Transducer:

#{ RX Transducer: #//
#* S2X [2.497] #// Forward (X)
#* S2Y [2.481] #// Starboard (Y)
#* S2Z [6.790] #// Downward (Z)
#} RX Transducer:

#{ Attitude 1, COM2: #//
#* MSX [0.00] #// Forward (X)
#* MSY [0.00] #// Starboard (Y)
#* MSZ [0.00] #// Downward (Z)
#} Attitude 1, COM2:

#{ Attitude 2, COM3: #//
#* NSX [0.00] #// Forward (X)
#* NSY [0.00] #// Starboard (Y)
#* NSZ [0.00] #// Downward (Z)
#} Attitude 2, COM3:

#{ Waterline: #//
#* WLZ [1.838] #// Downward (Z)
#} Waterline:

#} Location offset (m)

#} Locations

#{ Angular Offsets #// All angular offset parameters

#{ Offset angles (deg.) #//

#{ TX Transducer: #//
#* S1R [0.0] #// Roll
#* S1P [0.00] #// Pitch
#* S1H [359.98] #// Heading
#} TX Transducer:

#{ RX Transducer: #//
#* S2R [0.0] #// Roll
#* S2P [0.00] #// Pitch
#* S2H [.03] #// Heading
#} RX Transducer:

#{ Attitude 1, COM2: #//
#* MSR [0.00] #// Roll
#* MSP [-0.80] #// Pitch
#* MSG [0.0] #// Heading
#} Attitude 1, COM2:

#{ Attitude 2, COM3: #//
#* NSR [0.00] #// Roll
#* NSP [0.00] #// Pitch
#* NSG [0.00] #// Heading
#} Attitude 2, COM3:

#{ Stand-alone Heading: #//
#* GCG [0] #// Heading
#} Stand-alone Heading:

#} Offset angles (deg.)

#} Angular Offsets

#{ ROV. Specific #// All ROV specific parameters

#{ Depth/Pressure Sensor #//
#* DSF [1.00] #// Scaling:
#* DSO [0.00] #// Offset:
#* DSD [0.00] #// Delay:
#* DSH [NI] #// Disable Heave Sensor
#} Depth/Pressure Sensor

#} ROV. Specific

#{ System Parameters #// All system parameters

#{ System Gain Offset #//
#* GO1 [0.0] #// BS Offset (dB)
#} System Gain Offset

#{ Opening angles #//
#* S1S [0] #// TX Opening angle:
#* S2S [1] #// RX Opening angle:
#} Opening angles

#} System Parameters

#// ***
#// Runtime parameters

#{ Sounder Main #//

#{ Sector Coverage #//

#{ Max. angle (deg.): #//
#* MPA [70] #// Port
#* MSA [70] #// Starboard
#} Max. angle (deg.):

#{ Max. Coverage (m): #//
#* MPC [5000] #// Port
#* MSC [5000] #// Starboard
#} Max. Coverage (m):

#* ACM [0] #// Angular Coverage mode: MANUAL
#* BSP [2] #// Beam Spacing: HIDENS EQDIST

#} Sector Coverage

#{ Depth Settings #//
#* FDE [12] #// Force Depth (m)
#* MID [2] #// Min. Depth (m):
#* MAD [1000] #// Max. Depth (m):
#* DSM [0] #// Dual swath mode: OFF
#* PMO [0] #// Ping Mode: AUTO
#* FME [0] #// FM enable
#} Depth Settings

#{ Stabilization #//
#* YPS [1] #// Pitch stabilization
#* TXA [1] #// Along Direction (deg.):

#{ Yaw Stabilization #//
#* YSM [2] #// Mode: REL. MEAN HEADING
#* YMA [300] #// Heading:
#* HFI [1] #// Heading filter: MEDIUM
#} Yaw Stabilization

#} Stabilization
#} Sounder Main

#{ Sound Speed #//

#{ Sound Speed at Transducer #//
#* SHS [2] #// Source PROFILE
#* SST [14672] #// Sound Speed (dm/sec.):
#* Sensor Offset (m/sec [0.0] #//
#* Filter (sec.): [5] #//
#} Sound Speed at Transducer

#} Sound Speed

#{ Filter and Gains #//

#{ Filtering #//
#* SFS [2] #// Spike Filter Strength: MEDIUM
#* PEF [2] #// Penetration Filter Strength: MEDIUM
#* RGS [0] #// Range Gate: SMALL
#* SLF [1] #// Slope

```
    #* AEF                  [1] #// Aeration
    #* STF                  [0] #// Sector Tracking
    #* IFF                  [1] #// Interference
  #} Filtering

  #{ Absorption Coefficient #//
    #* ABC                  [5.360] #// 31.5 kHz
  #} Absorption Coefficient

  #{ Normal incidence sector #//
    #* TCA                  [5] #// Angle from nadir (deg.):
  #} Normal incidence sector


  #{ Mammal protection #//
    #* TXP                  [2] #// TX power level (dB): -20
    #* SSR                  [0] #// Soft startup ramp time (min.):
  #} Mammal protection
#} Filter and Gains

#{ Data Cleaning #//
  #* Active rule: [AUTOMATIC1] #//
  #{ AUTOMATIC1 #//
    #* PingProc.maxPingCountRadius [10]
    #* PingProc.radiusFactor [0.050000]
    #* PingProc.medianFactor [1.500000]
    #* PingProc.beamNumberRadius [3]
    #* PingProc.sufficientPointCount [40]
    #* PingProc.neighborhoodType [Elliptical]
    #* PingProc.timeRule.use [false]
    #* PingProc.overhangRule.use [false]
    #* PingProc.medianRule.use [false]
    #* PingProc.medianRule.depthFactor [0.050000]
    #* PingProc.medianRule.minPointCount [6]
    #* PingProc.quantileRule.use [false]
    #* PingProc.quantileRule.quantile [0.100000]
    #* PingProc.quantileRule.scaleFactor [6.000000]
    #* PingProc.quantileRule.minPointCount [40]
    #* GridProc.minPoints [8]
    #* GridProc.depthFactor [0.200000]
    #* GridProc.removeTooFewPoints [false]
    #* GridProc.surfaceFitting.surfaceDegree [1]
    #* GridProc.surfaceFitting.tukeyConstant [6.000000]
    #* GridProc.surfaceFitting.maxIteration [10]
    #* GridProc.surfaceFitting.convCriterion [0.010000]
    #* GridProc.surfaceDistanceDepthRule.use [false]
    #* GridProc.surfaceDistanceDepthRule.depthFactor [0.050000]
    #* GridProc.surfaceDistancePointRule.use [false]
    #* GridProc.surfaceDistancePointRule.scaleFactor [1.000000]
    #* GridProc.surfaceDistanceUnitRule.use [false]
    #* GridProc.surfaceDistanceUnitRule.scaleFactor [1.000000]
    #* GridProc.surfaceDistanceStDevRule.use [false]
    #* GridProc.surfaceDistanceStDevRule.scaleFactor [2.000000]
    #* GridProc.surfaceAngleRule.use [false]
    #* GridProc.surfaceAngleRule.minAngle [20.000000]
    #* SonarProc.use [false]
    #* SonarProc.gridSizeFactor [4]
    #* SonarProc.mergerType [Average]
    #* SonarProc.interpolatorType [TopHat]
    #* SonarProc.interpolatorRadius [1]
    #* SonarProc.fillInOnly [true]
  #} AUTOMATIC1

  #{ Seabed Image Processing #//
    #* Seabed Image Process [1] [0]
  #} Seabed Image Processing
#} Data Cleaning

#{ Advanced param. #//
#} Advanced param.
```

Appendix F: Software versions in use during EX1003

Software	**Version**	**Purpose**
CARIS HIPS and SIPS	6.1 Service Pack 2	Multibeam processing
ECDIS		Ship line keeping
Fledermaus	6.7.0h Build 419 Professional	Multibeam QC
Hypack	9.0.0.22	Surveyplanning

Hypack	9.0.4.0	Realtime monitoring
Kongsberg SIS (through 2/11/10)	3.6.1	EM302 data acquisition
Kongsberg SIS (installed 2/12/10)	3.6.4 build 174	EM302 data acquisition
Velociwin (NOAA)	8.92	XBT processing