APPENDIX E MOBILIZATION AND CALIBRATION REPORT

Mobilization Report – *R/V SHEARWATER*

US Wind Export Cable Route Offshore Survey

Ocean City, Maryland

REVISION HISTORY						
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1. Project Summary

1.1. MOBILIZATION SUMMARY

This report covers the mobilization of the hydrographic and geophysical survey equipment for the US Wind Export Cable Survey for the cable corridor offshore Ocean City, MD and the cable landing in Indian River Bay, DE. Survey personnel traveled to Ocean City, MD on 23-June-2016. The project vessel, the *R/V Shearwater* was already alongside at the USCG base in Ocean City, MD. Equipment mobilization onto the vessel commenced on 23-June-2016 and all equipment was fully installed, wet tested and calibrated on 25-June-2016. The following report contains details of all checks and calibrations that were carried out as part of this vessel mobilization.

Figure 1 – *R/V Shearwater*

1.2. FIELD PERSONNEL

The following key contractor personnel and client representatives were present on board the survey vessel:

Table 1 – Personnel on board

Party Chief	Daniel Whitesell
Navigation/Hydrographic Surveyor	Dario Manchia
Navigation/Hydrographic Surveyor	Marcus Kwasek
Geophysical Surveyor	Mitchell Kennedy

Geophysical Surveyor	Ben Manse
Processor	Cameron Morrissette
Processor	Brent Johnston
Captain	Wayne Porter
Captain	Mike Masek
Captain	Nick Jurich
Deckhand	Sean Kelleher
Deckhand	Joe Scotch
Cook	Bobby Lamton
US Wind Representative	Keir Miller

1.3. MAIN SURVEY EQUIPMENT

Table 2 – Survey Equipment

Equipment Type	Equipment Model
Primary GNSS	Applanix POS MV
Heading Sensor / Motion Sensor	Applanix POS MV
Multi-beam Echosounder (MBES)	RESON 7125
Side Scan Sonar (SSS)	Klein 3900
Sub-bottom Profiler (SBP)	Benthos CHIRP III
Magnetometer (MAG)	Geometrics G882 cesium vapor magnetometer
Ultra Short Base Line (USBL)	Sonardyne Scout Plus
Sound Velocity Probe (SVP)	Sontek CastAway CTD
Navigation, Multi-beam, Side Scan Sonar, Sub-bottom and Magnetometer Data Acquisition software	QPS QINSy, Klein SonarPro, CTI SonarWiz, Geometrics' MagLog

2. VESSEL CONFIGURATION, OFFSETS AND INTERFACING

2.1. OFFSETS

In November of 2012 all equipment installation and other reference points of interest on the *R/V Shearwater* were surveyed in using conventional land survey techniques. All equipment offsets for the US Wind Export Cable Survey were verified with a metric tape measure and double-checked by the survey crew. The x-axis is positive to starboard; y-axis is the vessel's longitudinal center-line, positive forward and z-axis is positive upwards. In June of 2015, a survey control point was established quayside at the USCG facility in Ocean City, MD and was used to verify positioning and heading sensor calibration.

VESSEL :	R/V Shearwater			
OFFSET from IMU	☑ meter ☐ feet	+ forward/ - backward	right/ - left	+ up/ - down
Primary GPS Antenna		0.978	-1.591	5.043
Secondary GPS Antenna		-0.974	1.808	5.042
IMU (Intertial Measurement Unit)		0.000	0.000	0.000
Waterline				-3.959
Multibeam Echosounder		3.037	-0.729	-6.070
USBL Tranceiver		-0.780	4.206	-6.551
Subbottom Transducer		-0.628	3.825	-6.286
Side Scan Block Sheive		-16.810	0.005	-3.959
Magnetometer Piggyback Offset from SSS		-10.000		

Figure 2 – *R/V Shearwater* Offsets

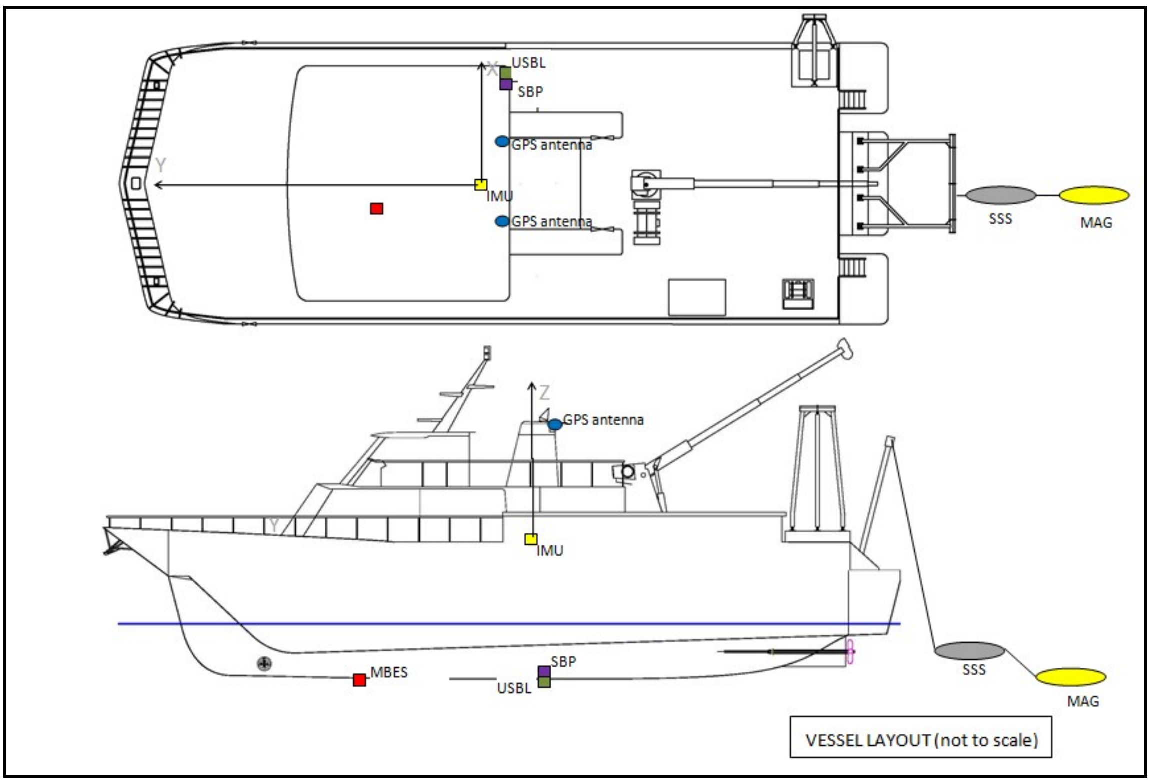

Figure 3 – *R/V Shearwater* Offset Diagram

2.2. EQUIPMENT INTERFACING

All inputs/outputs from the survey online equipment were checked as detailed:

Table 3 – Equipment Interfacing

QINSy INPUT	Transmission Parameters
Ethernet for POS MV – Positioning, Motion, Timing	129.100.1.1/ Port 5602
Reson 7125 MBE data – via TCP/IP	

APPLANIX INPUT	Transmission Parameters
USCG DGPS Corrections	Baud 9600

APPLANIX OUTPUT	Transmission Parameters
To RESON 7125 - ZDA	Baud 9600; Update 1 Hz
To RESON 7125 – Binary TSS1 Motion	Baud 57600; Update 50 Hz
To RESON 7125 – PPS Timing	BNC/TTL
Ethernet to QINSy – Positioning, Motion, Timing	129.100.1.1/ Port 5602

RESON 7125 INPUT	Transmission Parameters
Applanix Time Stamp – ZDA	Baud 9600; Update 1 Hz
Applanix Motion – Binary TSS1 Motion	Baud 57600; Update 50 Hz
Applanix Timing – PPS Timing	BNC/TTL

KLEIN 3900/SONARPRO INPUT	Transmission Parameters
QINSy Corrected Navigation – NMEA GGA, VTG, ZDA	Baud 4800; Update 5 Hz (ZDA 1 Hz)

Benthos CHIRP III INPUT	Transmission Parameters
QINSy Corrected Navigation – NMEA GGA, VTG	Baud 9600; Update 2 Hz

GEOMETRICS G882/MAGLOG INPUT	Transmission Parameters
QINSy Corrected Navigation – NMEA GGA, VTG	Baud 9600; Update 1 Hz
Magnetic data, altitude, and depth from towfish	Baud 9600; Update 10 Hz

3. PROJECT CONTROL

3.1. Geodetic Reference System

The survey data acquisition and data post processing project geodesy is WGS-84 UTM zone 18N meters.

Table 4 – Project Geodesy

PROJECT GEODESY	
Ellipsoid	WGS-84
Semi Major Axis	6378137.000m
Inverse Flattening	298.257223563
Transformation Method	N/A
Coordinate System	UTM
Projection Method	Transverse Mercator
Zone	18 North
Central Meridian	75°00’00.000” W
Reference Latitude	00°00’00.000” N
False Easting	500,000.000
False Northing	0.000
Scale Factor	0.99960000
Survey units	Meters (m)

3.2. POSITIONING CONTROL

The vessel's reference point (X=0, Y=0, Z=0) is the IMU (Inertial Measurement Unit) reference position.

3.3. GNSS SYSTEM

Primary navigation for this project is an Applanix POS MV DGNSS (*Differential Global Navigation Satellite System*) interfaced with a Trimble NavBeacon USCG beacon receiver which uses a local USCG (United States Coast Guard) reference station in order to calculate a differential correction for the vessel’s location.

3.4. GNSS SYSTEM VERIFICATION

A position verification was conducted on 25-August-2016 alongside the USCG in Ocean City, MD.

In June of 2015, during the previous US Wind survey, a control point was established on a quayside structure near the aft of the vessel dock in Ocean City, Maryland. A PK nail was installed by a professional land surveyor (Geomatix) on a center piling in a dolphin structure at the USCG facility. This survey point was used to vessel positioning.

To verify vessel positioning accuracy a comparison was made between the vessel reference point (IMU) and the survey benchmark established dockside at the USCG facility. The distance between the benchmark and the IMU was measured physically with a measuring tape, while logging the position of the IMU. The geodetic distance between the IMU and benchmark was calculated and compared to the hand-measured distance. Results of this comparison are presented in the table below. The results are within the expected stated accuracies of the DGNSS system.

Table 5 – DGNSS Positioning Verification

DGNSS Positioning Verification			
Positioning Check	Geodetic Distance (m) Global Mapper Measured	Observed Distance(m) Hand Measured	Delta (m)
OPUS point to IMU	13.791	14.172	0.396

3.5. HEADING CONTROL

3.5.1. Heading Sensor System

The Applanix POS MV system provides motion, heading and position information by integrating data from both inertial and GNSS sensors. The system comprises a MRU inertial measurement system and two Trimble GNSS carrier phase receivers. Heading is derived from GNSS phase comparison techniques between the two GNSS antennae. Receivers were mounted in a port-starboard fashion just behind the wheelhouse of the *R/V Shearwater*.

3.5.2. Gyro Alignment

To determine the precise offsets of the inertial and GNSS sensors a GPS Azimuth Measurement Subsystem (GAMS) Solution was calculated as follows:

- The GAMS calibration was performed when the number of satellites in view exceeded 5 with PDOP less than 3.0. If the GPS environment is OK, and SVs do not fix within 45 minutes, there may be a multipath problem. This will be adjusted prior to starting GAMS calibration
- The vessel was maneuvered through a series of turns (figure 8's) incorporating changes of speed and direction.
- The operator then waits for the Heading Accuracy to show accuracy below the threshold value entered (more than zero and less than 1 degree - trying to obtain lowest value possible) and for the GAMS Status to show Ready Offline.
- Vessel motion was then stopped and the vessel held at constant heading.
- GAMS Calibration was then started.
- Once the GAMS calibration was complete the values are saved into the system.

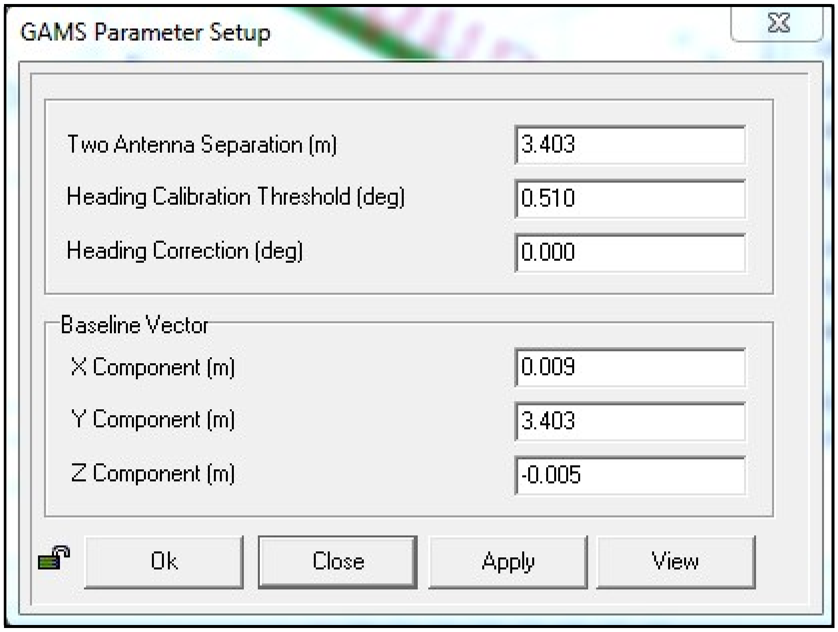

Figure 4 – Screenshot of GAMS Parameter setup

Table 6 – GAMS Results

Port Ant. to Starboard Ant.	GAMS
Delta X	0.009
Delta Y	3.403
Delta Z	-0.005

3.5.3. Heading Verification

Two benchmarks installed at the USCG dock, described in Section 3.4 above, were used to provide an accurate baseline to compare against the heading derived by the Applanix POS MV system onboard the vessel. Following the GAMS calibration the vessel was pulled up alongside the dock at Ocean Yacht Marina between the two installed benchmarks. The vessel dock lines were made fast and tight as possible against the dock but it should be noted that due to its size and the need for bumpers, the vessel cannot be in exact alignment with the pier bulkhead.

The baseline value between the two benchmarks (205.11°) was measured in global mapper while a heading solution was recorded from the POS MV for 2. A total of 28,041 heading measurements were made with the Applanix POS MV system and compared to the baseline value. The results of the heading checks and their delta value are presented below.

Table 7 – Heading Check

Baseline Heading	Applanix POS MV Heading	Delta Heading
205.11°	204.74°	0.37°

4. SOUND VELOCITY PROFILER

During mobilization at the USCG facility in Ocean City, MD, two Sontek CastAway CTD probes were brought onboard the *R/V Shearwater*.

The first CastAway system was deployed from the *R/V Shearwater* prior to the start of the MBES patch test. Data from the probe were downloaded into QINSy for proper depth and beam steering calculation. The second CastAway system was kept on-board the vessel as a back-up. A comparison of SVS installed at the head of the transducer and a simultaneous SVP cast can be seen below.

Prior to the MBES patch test both SVPs were wet tested simultaneously. They were given time to acclimate at the surface and then deployed to a depth of 11m. The data were recorded on the internal memory of each probe, downloaded and compared. The results can be seen in the graph below:

Table 8 – SVP Comparison

SVS at transducer	SVP at 2.1 meters
1526.5 m/s	1525.3 m/s

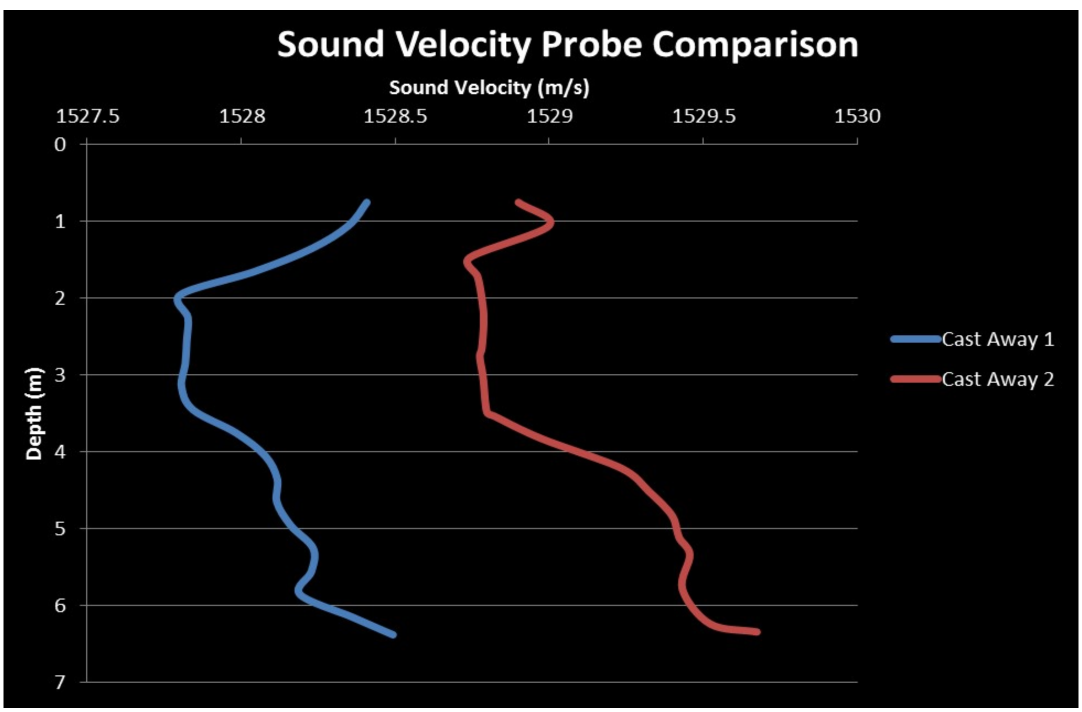

Figure 5 – SVP Comparison

5. ECHO SOUNDER – MULTI-BEAM SYSTEM

A RESON 7125 Multi-beam Echosounder system is installed in the center hull moon pool aboard the *R/V Shearwater* and will be used to provide swath bathymetry data. Main instrumental and operating parameters are as follows:

Table 9 – Multibeam System

Multi-beam echo sounder	RESON 7125
Transducer mount	Hull mounted in moon pool
Motion reference unit	Applanix POS MV
Sound velocity probe	Sontek CastAway

Operating Parameters	
Transducer Frequency	400 kHz (may be adjusted during survey to minimize cross talk)
Acquisition software	QINSy
Velocity Sensor at Td	Valeport
General water depth	3-25 m
Average ship's speed	4 knots
Coverage	~5x Water Depth
No of beams	512

Prior to sailing, vessel draft was recorded and used to calculate the waterline value for the transducer. The draft values will be observed and recorded once a day throughout the survey for post-processing ending with a final draft measurement

A patch test was conducted on 25-June-2016 to establish the correct mounting offset angles for the MBE system. The patch test consisted of setting the mounting angle values in the acquisition software to 0.00, and running a standard set of patch test lines for a MBE system.

A calibration site was chosen one hour from Ocean City Inlet in 20 meters water depth. The data were acquired in QINSy Version 8.10. Data were processed in Caris HIPS version 9.1 in WGS84 UTM Zone 18N meters.

Three navigation lines were designed to run over a navigation channel slope as well as an area of flat seafloor. Two of the lines were run in both directions to ensure enough coverage to allow for proper calibration, and a third cross line (perpendicular to the first two lines) was run for a QA/QC check. A secondary patch test was chosen over a known shipwreck and was conducted on 10-June-2016 to better adjust for motion artifacts. The secondary patch test was used for final motion values as the pitch calibration was determined to have improved. The patch test results were keyed into the multibeam acquisition software for the survey.

One line run in opposite directions, with overlapping swaths, was utilized to calibrate for roll.

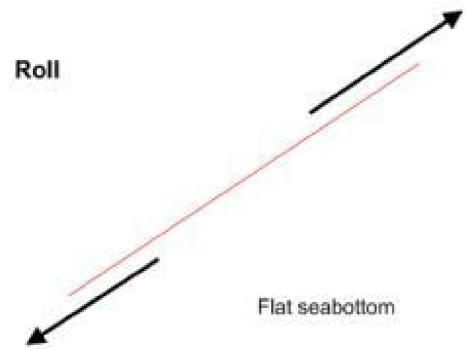

Figure 6 – Roll Calibration

One line run in opposite directions was utilized to calculate the pitch offset of the transducer.

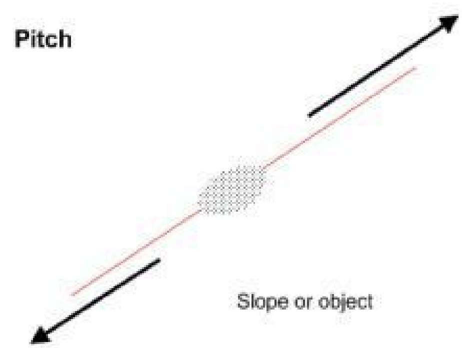

Figure 7 – Pitch Calibration

Two lines run in the same direction but with a slight offset to allow the swaths to overlap over the object were utilized to calibrate the yaw of the transducer.

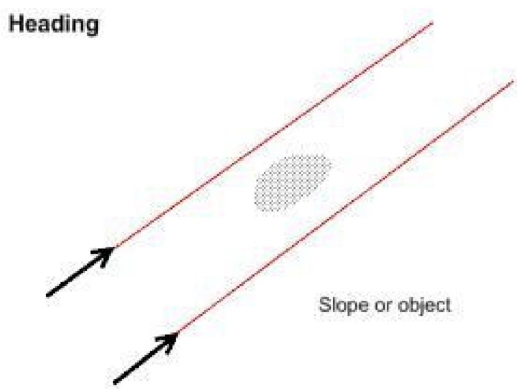

Figure 8 – Yaw Calibration

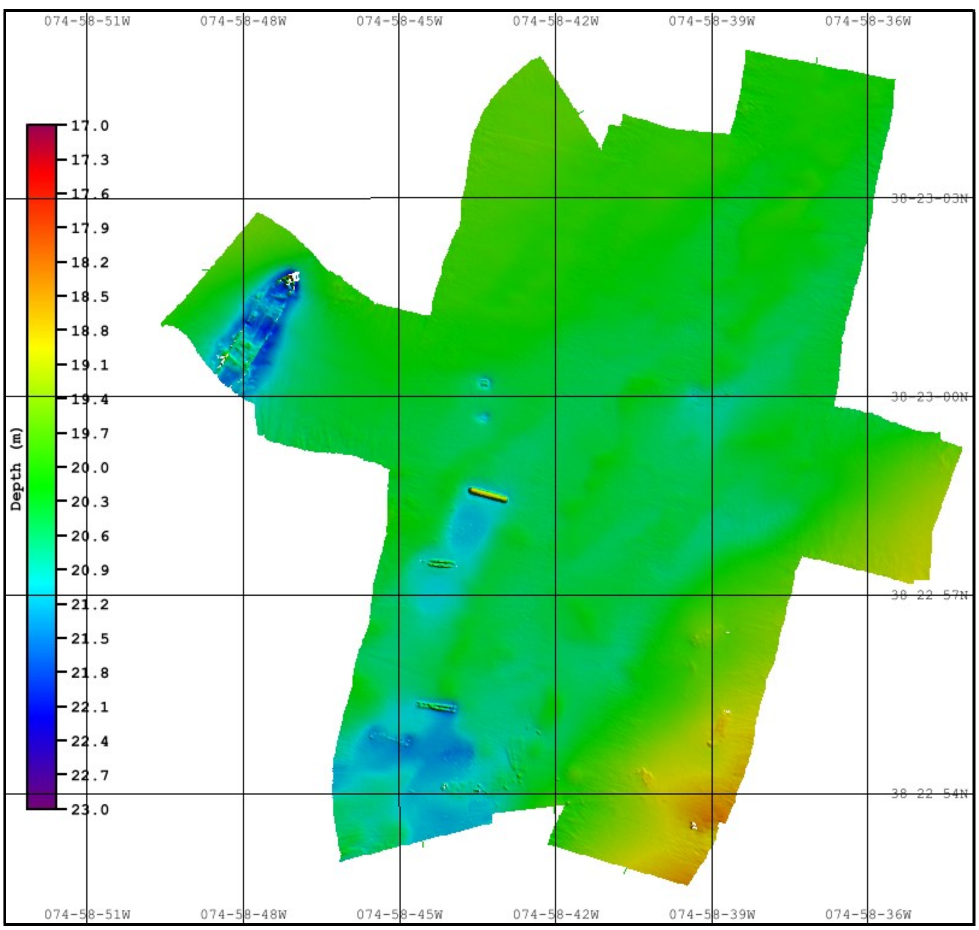

Figure 9 – Patch Test Results

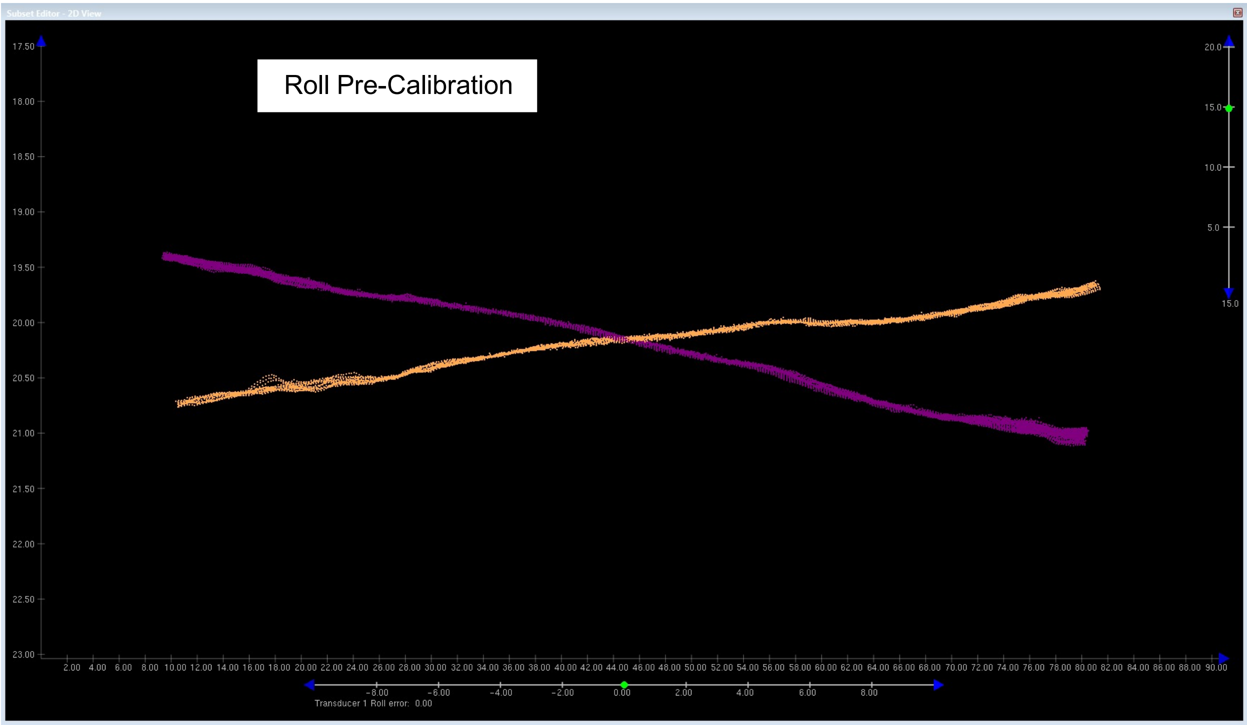

Figure 10 – Roll Pre-Cal

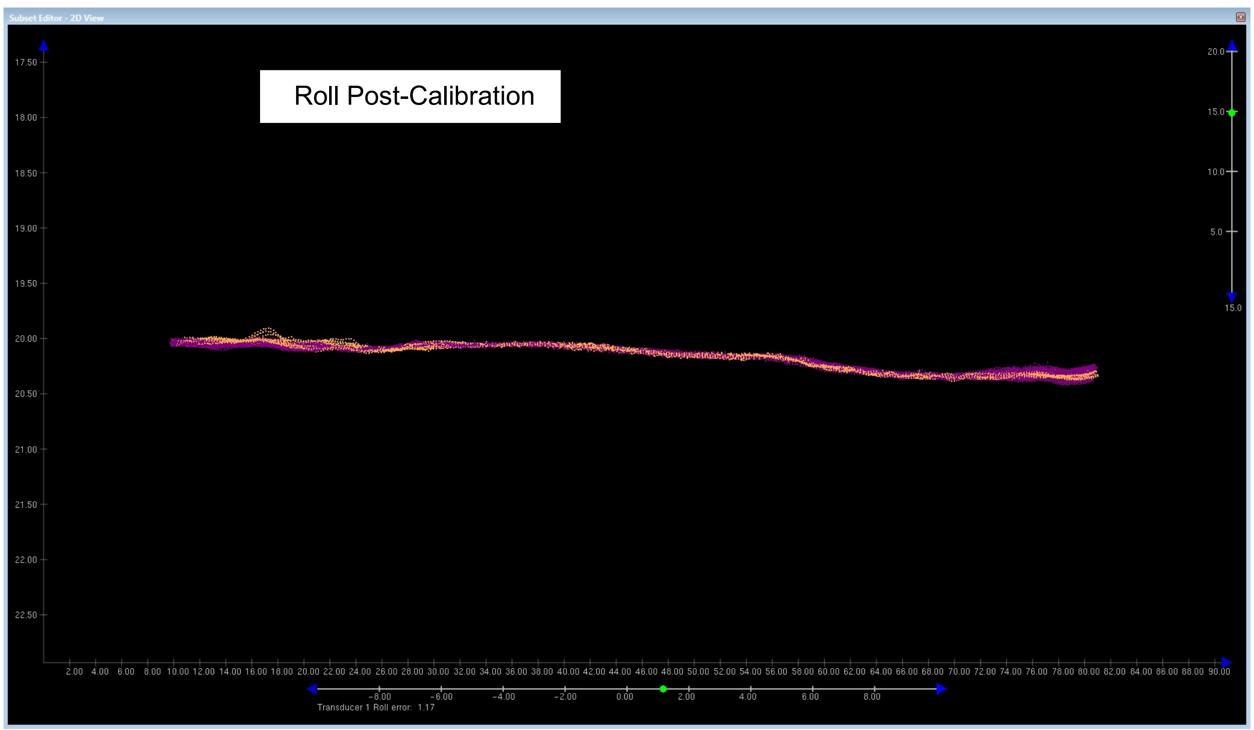

Figure 11 - Roll Post-Cal

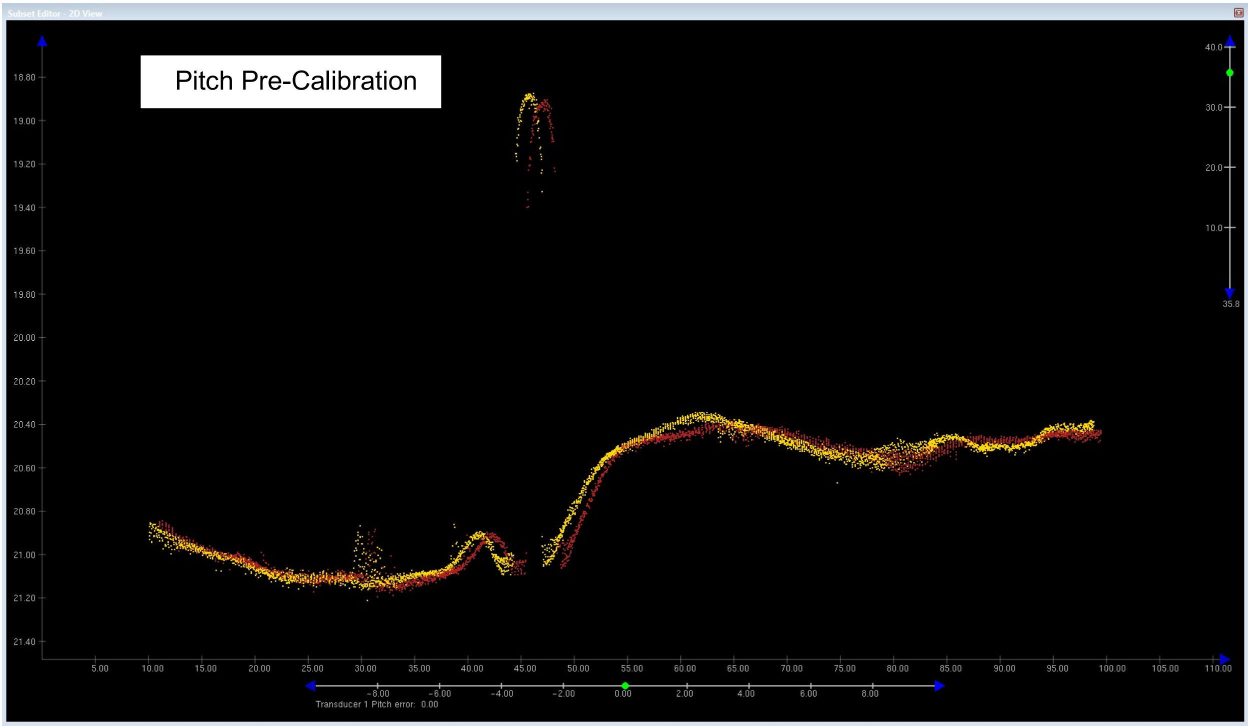

Figure 12 - Pitch Pre-Cal

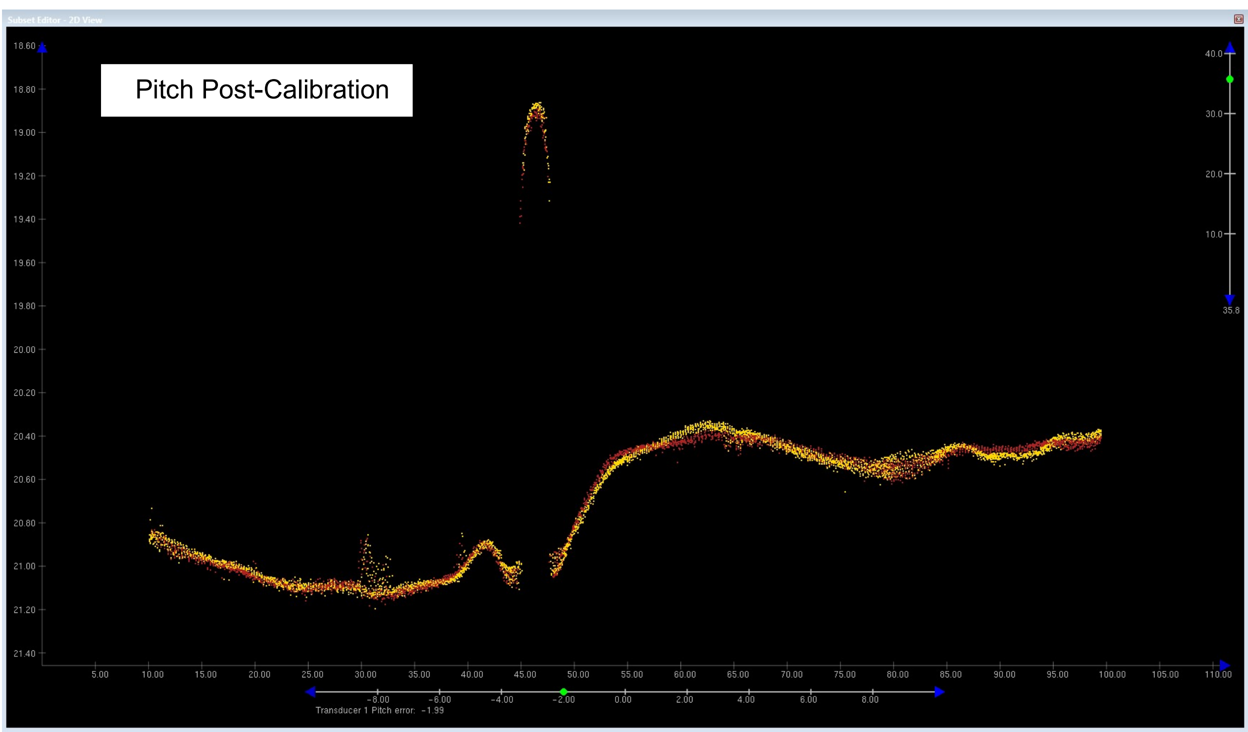

Figure 13 - Pitch Post-Cal

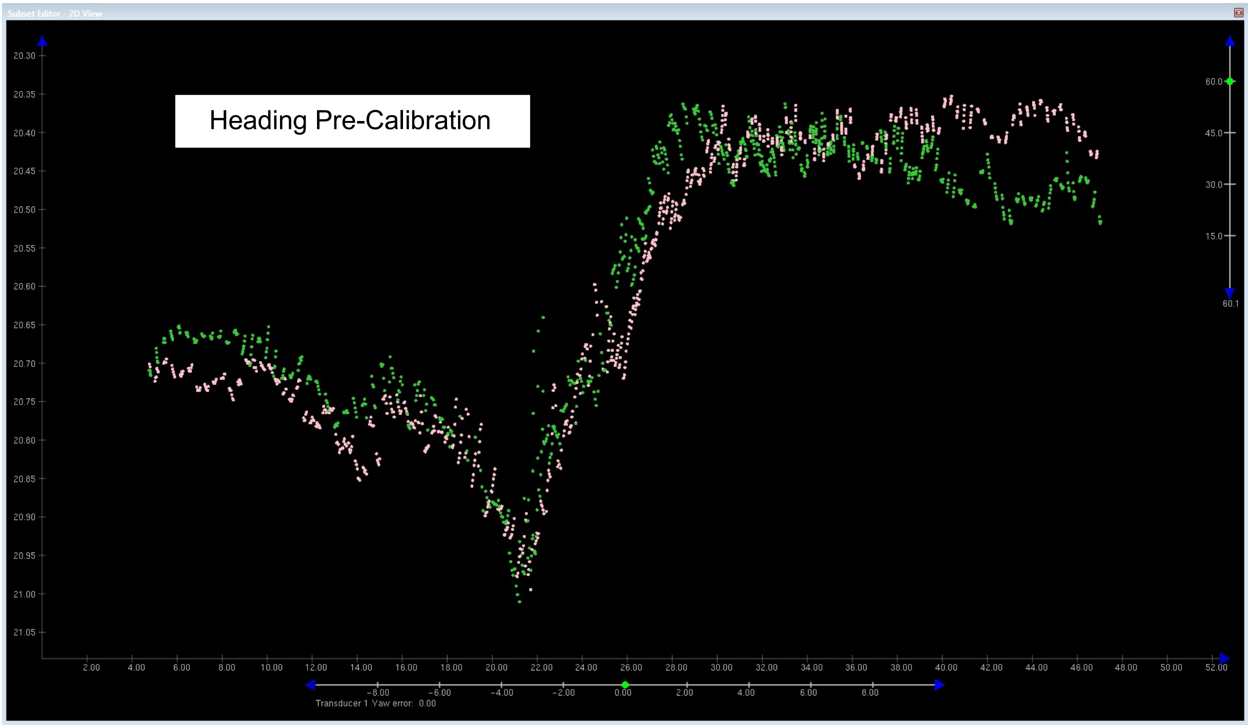

Figure 14 - Heading Pre-Cal

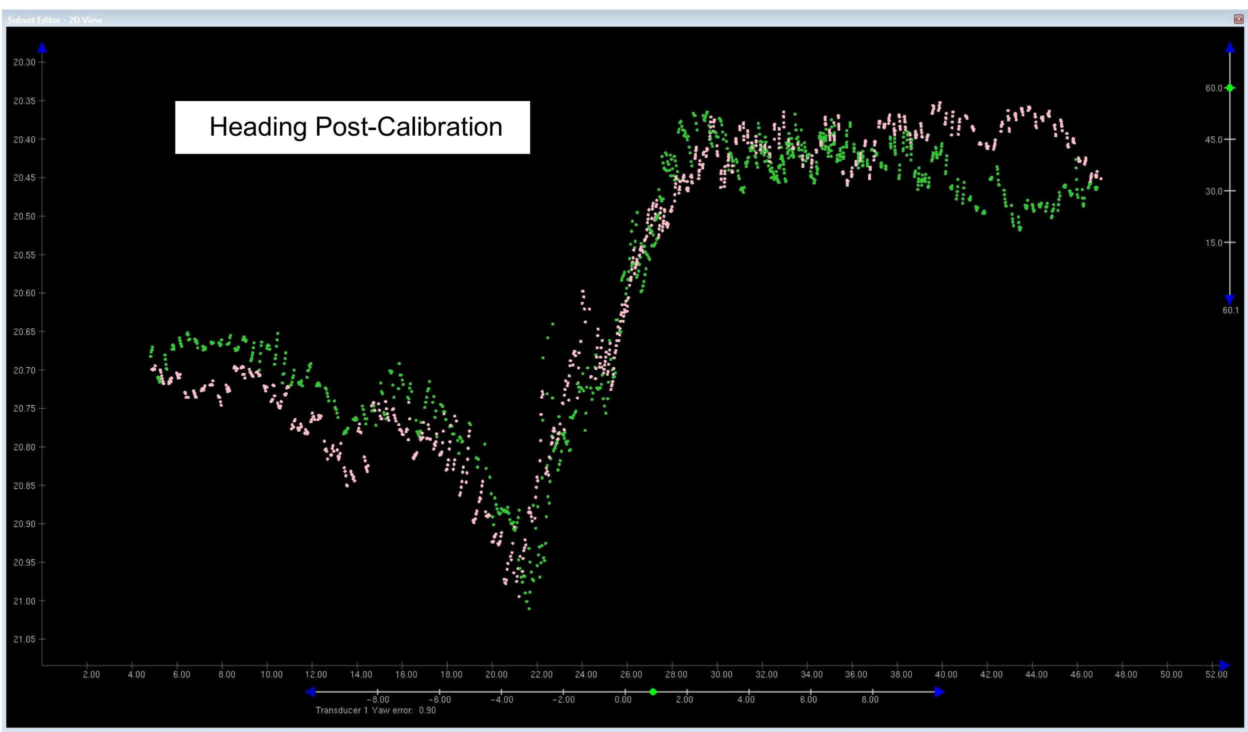

Figure 15 - Heading Post-Cal

Table 10 - Patch Test Results

RESON 7125 Calibration Results	
Roll	1.17°
Pitch	-1.99°
Heading	0.90°

6. SIDE SCAN SONAR CHECK

The Klein 3900 Side Scan Sonar system was wet tested and data were collected to ensure proper acoustic imagery acquisition. The data were processed in SonarWiz version 5.0 to generate a mosaic and verify object detection and positioning. The specification for this project is to collect SSS at range scales in which 100% overlap is obtained in the all sections of the export corridor. Side scan imagery showing detection of sand ripples can be seen below.

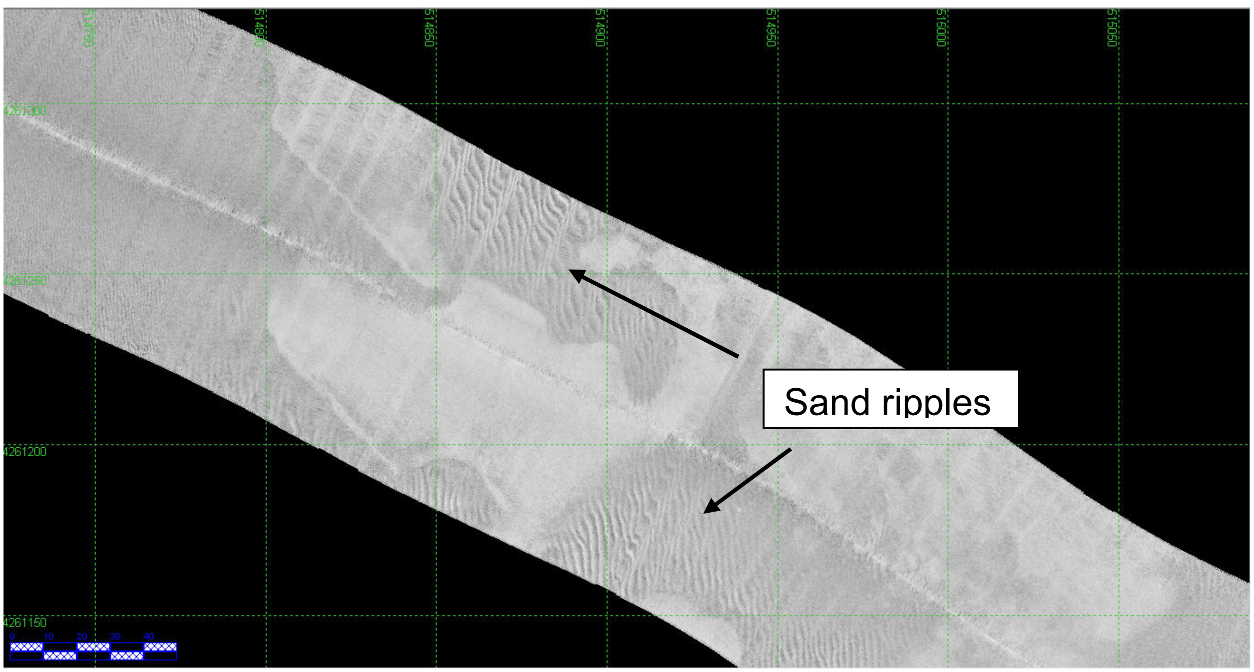

Figure 16 - Side Scan Sonar Check

7. SUB-BOTTOM PROFILER CHECK

During mobilization at the USCG dock in Ocean City, MD, the CHIRP subbottom transducer was installed in the *R/V Shearwater's* moon pool on the starboard side of the vessel. On 25-August-2016 the system was tested to ensure proper penetration and acoustic transmission. The sub-bottom system was powered on and the vessel moved underway to verify for acoustic transmission, receiving and for interfacing with the navigation system. A profile of collected data below shows approximately 15 meters of penetration.

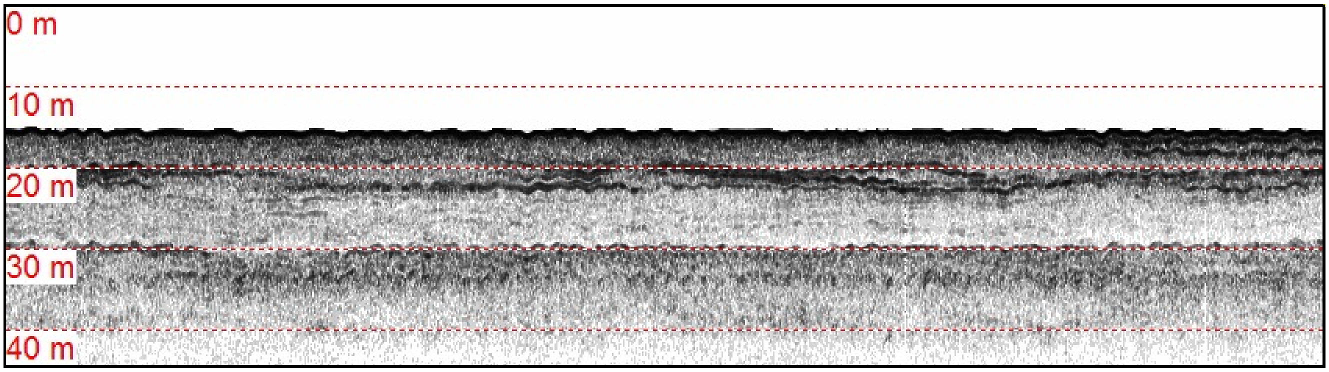

Figure 17 – Sub-bottom Data Example

8. USBL Calibration

A Sonardyne Scout Plus USBL transceiver was installed in the starboard moon pool of the *R/V Shearwater* on 23-August-2016 at approximately a 30° pitch angle towards the stern. This was done to receive more accurate acoustic updates as the transponder beacon would be attached on the towfish behind the vessel. A calibration of the USBL transceiver system was conducted on 8-June-2016 outside the Newport News Channel. The calibration entailed running a star-shaped pattern of lines as seen below.

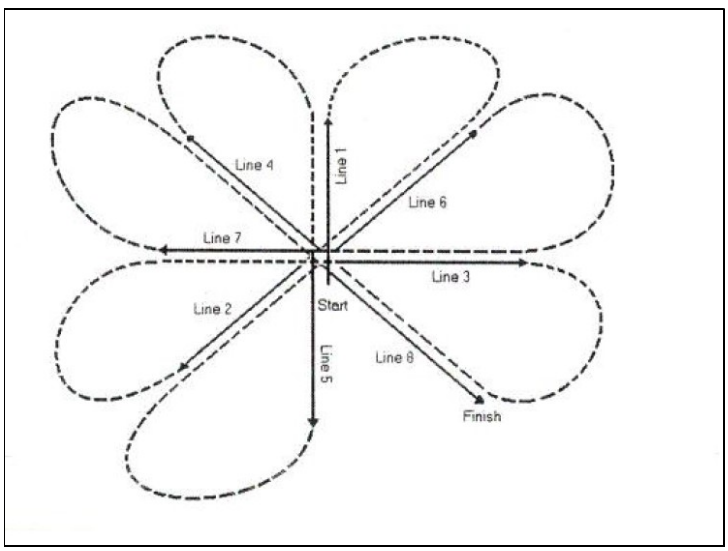

Figure 18 - USBL Calibration Pattern

This pattern centers on a USBL beacon that was deployed down to the seafloor at a depth of approximately 20 meters and buoyed to the surface for location and recovery. The USBL data were collected as the vessel was moving slowly away from the transponder as seen in the *R/V Shearwater's* track lines from the calibration below.

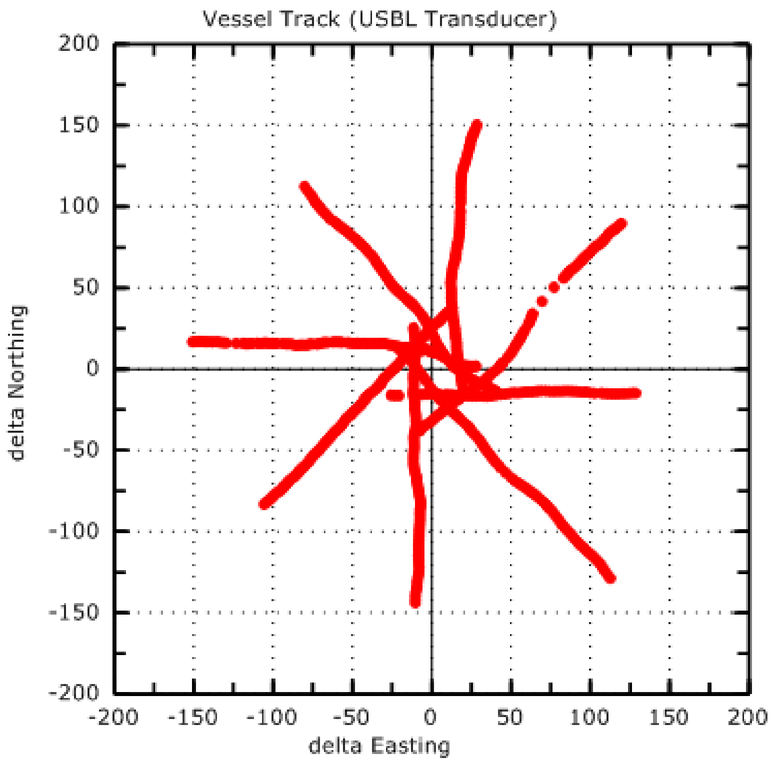

Figure 19 - USBL Calibration Lines

The data collection does not begin until the vessel passes by the transponder beacon in the water and is receiving acoustic positions. The vessel got no closer to the transponder beacon than the water depth at which the transponder beacon was deployed. The data was collected over a distance of approximately 60 meters on each line which is 3 to 4 times the water depth of the beacon.

After running all lines, USBL data were processed in QINSy's calibration utility. The results for roll angle, pitch angle and heading angle can be seen below.

Table 11 - USBL Calibration Results

Roll angle	Pitch angle	Heading angle
-2.83°	-28.82°	4.15 °

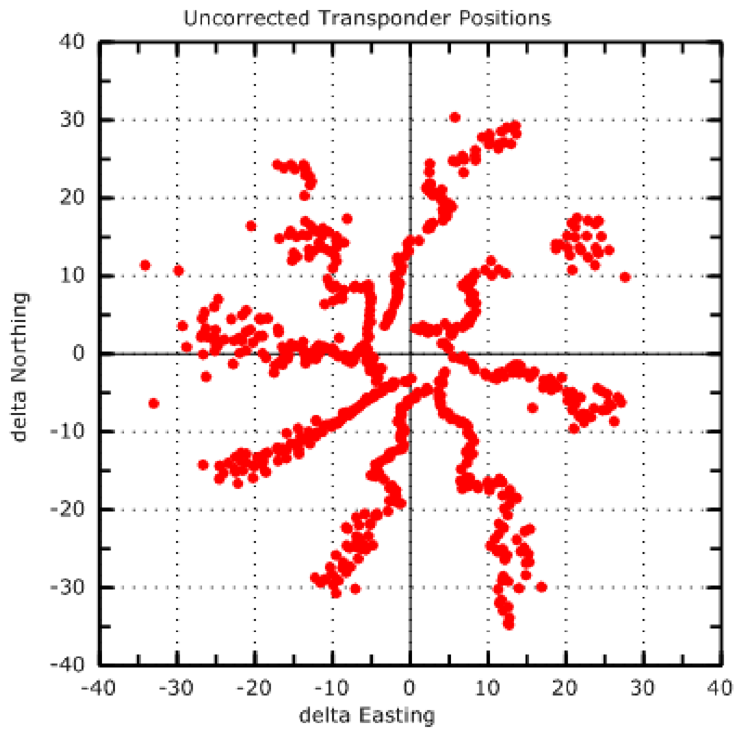

Figure 20 - USBL Positions Pre-Cal

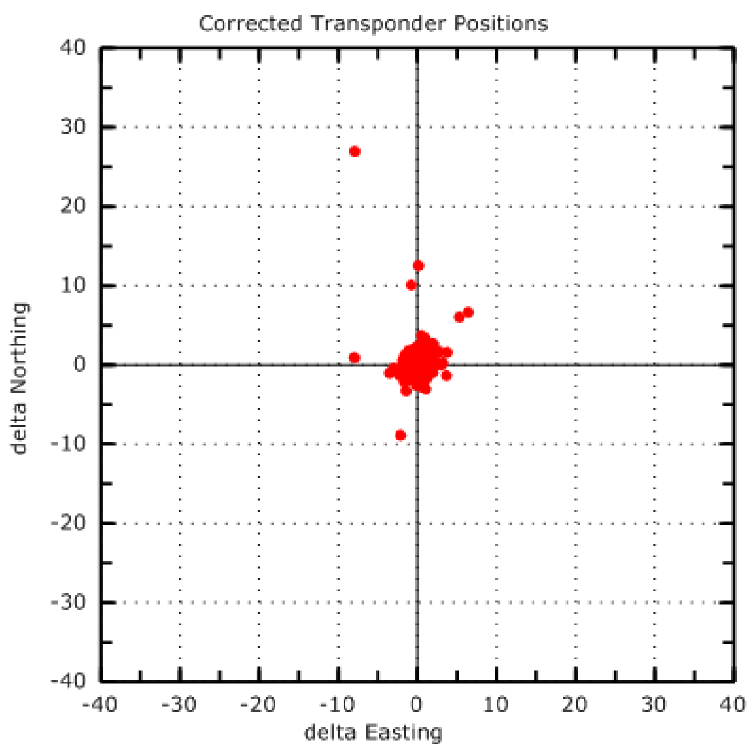

Figure 21 - USBL Calibration Positions Post-Cal

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