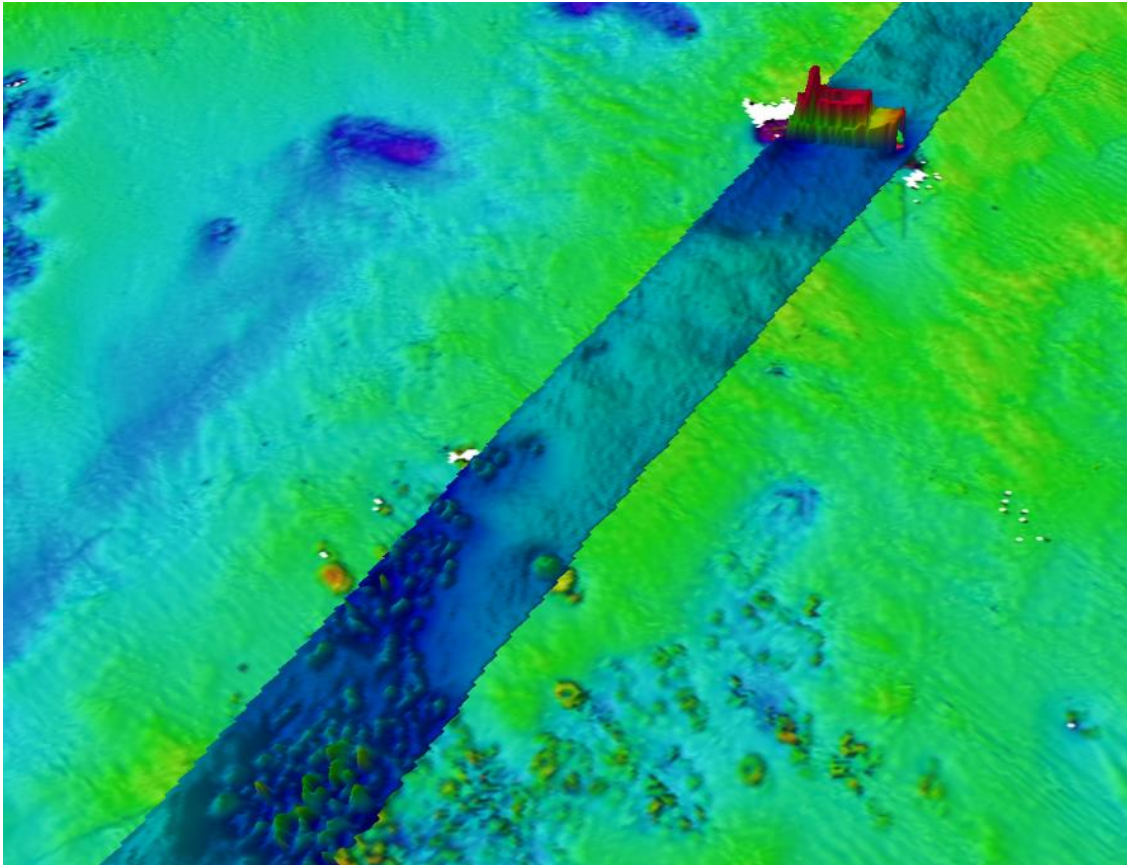# R/V *Hugh R. Sharp*
Reson 7125 SVP2
Multibeam Echosounder System Calibration
March 21-23, 2016

Report prepared by:

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Cover image: A shipwreck and tire dumping ground at the Redbird Reef site observed with the Reson 7125 aboard the R/V *Hugh R. Sharp* during HRS1602 overlain on background bathymetry collected by the NOAA Ship *Ferdinand R. Hassler*. Vertical scales of the *Sharp* and *Hassler* data are 3X and 0X, respectively, with various depth color scales.

Introduction

The R/V *Hugh R. Sharp* is equipped with a Reson 7125 SVP2 (200/400 kHz) multibeam echosounder installed on a drop keel and an Applanix POS-MV 320 positioning and attitude system. Traditionally, survey planning and data acquisition are handled using Hypack HYSWEEP software installed on the RESON acquisition machine. These systems were reviewed by personnel from the Multibeam Advisory Committee (MAC), University of Delaware (UDEL), and Reson during sea acceptance trials in October 2012 with satisfactory results and have been used for very high quality mapping exercises (e.g., evaluation of bedform migration at the 'Redbird Reef' artificial reef site before and after major storms).

Given the seasonal removal/reinstallation of the Reson 7125, frequent drop keel adjustment (e.g., retracted dockside and extended at sea), and personnel changes since sea trials in 2012, the MAC was asked to review the most recent Reson 7125 installation and perform a patch test prior to the summer 2016 operational season. Preliminary review of the system configuration and functionality testing were performed dockside on March 21 and a patch test was performed during a public day cruise (HRS1602) on March 22 at the 'Redbird Reef' artificial reef site. This site was much shallower (20-30 m) than ideal depths for calibration of angular offsets, but included many submerged targets making distinct features for latency, pitch, and yaw calibration, plus ample 'flat' seafloor for roll calibration. This document describes the system geometry review, patch test procedure and results, and recommendations for operation.

In addition to remote support provided by Val Schmidt (UNH), Glen Rice (NOAA), Vitad Pradith (Hypack), and Paul Johnson (UNH), on-board participants in multibeam operation during HRS1602 included:

1. Timothy Deering (UDEL)
2. Jon Swallow (UDEL)
3. KG Fairbarn (UDEL)
4. Art Trembanis (UDEL)
5. Vicki Ferrini (LDEO)
6. Kevin Jerram (UNH)

Survey System Components

The mapping system consists of the following components:

1. Reson 7125 SVP2/FP3 multibeam echosounder (200/400 kHz) with surface velocimeter
2. Applanix POS-MV V5 inertial motion sensor: s/n 5250
3. Seabird 911 conductivity-temperature-depth (CTD) sensor
4. Hypack 2016 data acquisition software

Overview of System Geometry

In this report, we use the term 'system geometry' to mean the reference frame(s) of the vessel and the linear and angular offsets of the primary components of the multibeam mapping systems, including the TX array, RX array, and motion sensor. These parameters are critical for data collection in an unbiased and repeatable manner. Figure 1 provides an overview of the sensor layout and Table 1 provides an outline of available documentation describing the system geometry.
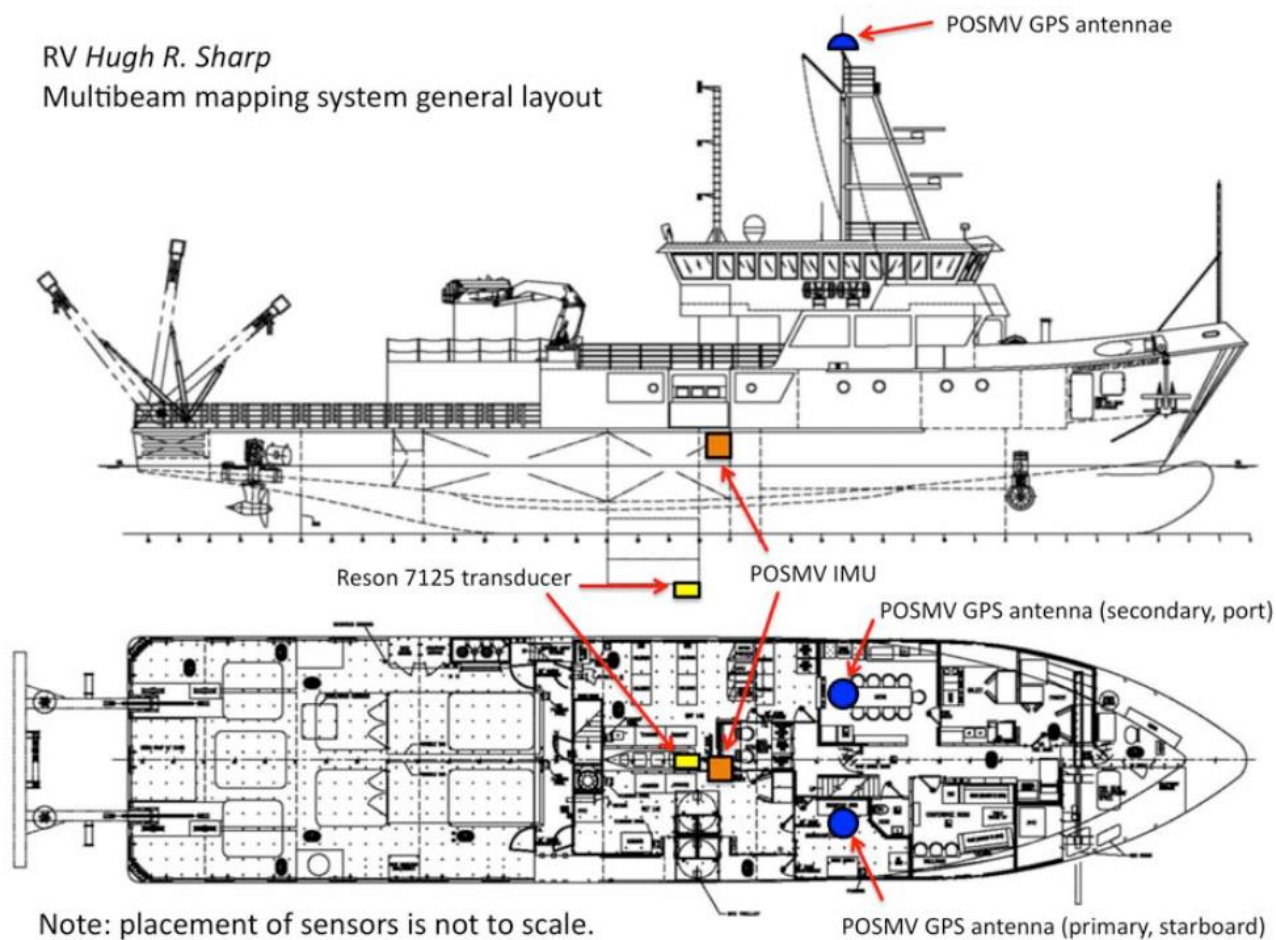
Figure 1. General layout of multibeam mapping system components.

Table 1. Documentation for system geometry aboard the R/V Hugh R. Sharp.

Date	Location	Event	References
2009		Vessel survey including motion sensor, antenna, and sonar plate	Survey diagram provided by R/V *Hugh R. Sharp*
2012-Oct	Delaware Bay, DE	Sea acceptance trials; calibration of 7125; updated angular offsets	R/V *Hugh R. Sharp* SAT report (http://mac.unols.org)
2013-May		Corrected vertical offsets for Hypack configuration at each drop keel position (entered for the Reson SeaBat 7125 in Hypack)	R/V Hugh R. Sharp Hypack Configuration (2013, p. 7) (http://mac.unols.org)
2016-Mar	Delaware Bay, DE	Calibration of 7125; updated angular offsets	This document (http://mac.unols.org)

Documentation of the original system installation and geometric calibration during sea trials included a survey report and screenshots of the Reson, Applanix, and Hypack software configuration (http://mac.unols.org). All offsets implemented at that time were based on a 2009 vessel survey (performed by NOAA, according to Tim Deering of UDEL) and measurements made by the Reson technician during installation and sea trials. Aside from removing and reinstalling the Reson 7125 on the drop keel transducer pod as needed for science cruises, it was reported during HRS1602 that no modifications have been made to the vessel, motion sensor, or antenna installations since 2012.

The vertical position of the transducer pod depends directly on the drop keel position used during survey, and this value is reflected in the transducer vertical offset applied in Hypack during acquisition. It was discovered after the 2012 sea trials that the drop keel control bolts designed to provide flush, 1-m, and 2-m extension of the transducer pod were machined with 1-yard spacing. Updated vertical offsets for the transducer in the Hypack frame (with respect to waterline, not IMU) were provided in May 2013 (http://mac.unols.org). In the absence of more recent vessel surveys or further corrections, the vertical offsets for each drop keel position provided in 2013 were applied during HRS1602 and shall continue to be used for data collection moving forward.

Horizontal control of the transducer drop keel is accomplished with an airbag system that 'pins' the drop keel within the vessel frame. Though this has not been investigated directly, this airbag system likely secures the drop keel within acceptable tolerances for horizontal positioning uncertainty. Furthermore, the horizontal offsets are assumed to be constant in the ship reference frame for all drop keel positions (i.e., the drop keel moves purely in the vertical direction in the vessel reference frame). Dockside review of the available documentation confirmed correct translation of the sensor linear offsets into the Reson, POS-MV, and Hypack configurations using a vessel reference frame centered at the IMU. The only exception to this convention is that Hypack uses a waterline reference for vertical offsets; the 2013 updated Hypack configuration relative to waterline was maintained for HRS1602.

It is important to note that all angular offsets in multibeam mapping system are attributed exclusively to the transducer installation in the vessel reference frame. Several factors lead to this approach, which is different from most vessels visited by the MAC. First, the motion sensor has not been surveyed for its angular offsets in the vessel reference frame; these values for IMU pitch, roll, and yaw are thus treated as zero in absence of other information. Second, the high-frequency Reson 7125 transducers are small compared to the much larger, lower-frequency arrays installed in the hull of other UNOLS vessels. Whereas larger arrays aboard other vessels are installed separately and require individual measurements of linear and angular offsets for proper configuration, the Reson 7125 RX and TX transducers are installed on a high-precision factory bracket with known local offsets. It is thus assumed that both 7125 transducers share identical angular offsets in the vessel reference frame. Third, the removal and reinstallation of the transducers on the drop keel is likely the dominant source of angular offset variability in the mapping system.

Geometric Calibration

After review and confirmation of all linear offsets, the 7125 was calibrated for angular offsets using the 200-kHz transmit mode and a drop keel position of 3' below the hull. A sound speed profile was calculated from a CTD profile collected immediately prior to calibration, showing a well-mixed water column and nearly constant sound speed of 1478 m/s. As recommended by ship personnel familiar with the survey site, tide data from Atlantic City, NJ, was applied with zero time offset and a scaling factor of 0.9. To achieve high ping rate and sounding density, the ship was operated at 6 kts for all calibration lines (except latency) and the total swath widths were adjusted as follows:

Latency:	30°
Pitch:	30°
Roll:	140°
Yaw:	110°

Calibration tools in QPS Qimera were used by Jerram and Ferrini to evaluate each set of calibration lines, verify no observable positioning latency in the data available, and determine angular offsets for the Reson 7125. Figures 3-5 provide examples of the sounding subsets used for calibration, and Tables 2-3 provide summaries of the post-HRS1602 mapping system offsets in the vessel and Hypack frames. These results are based on the available vessel survey documentation and calibration results; accordingly, these values are to be applied until sensors are modified or another calibration becomes necessary, such as after removal and reinstallation of the transducers.

Table 2. Sensor offsets after system geometry review and calibration during HRS1602; only the 7125 angular offsets were modified, with all other linear offsets maintained from the 2013 updated configuration provided by the MAC. Note that the values in this table represent the documented physical layout of sensors using a vessel reference frame centered at the IMU and a given sign convention. The spacing between acoustic centers of the TX and RX arrays at each frequency is given by the Reson schematic copied in Figure 2, showing that the RX array acoustic center is forward of the TX array acoustic center by 0.20 m at 200 kHz and 0.18 m at 400 kHz. At both frequencies, the RX array acoustic center is 0.024 m below the TX array acoustic center. These values are included here for complete description of the physical sensor layout. The sensor and data collection software configurations tend to require only the sonar reference point (TX acoustic center) and use reference frames and/or sign conventions different from those in this table. Table 3 provides the Hypack configuration, and screenshots of all configurations are available in the Appendix.

Drop Keel	Sensors in VESSEL frame Origin at IMU	Alongship BOW +	Athwartship STBD +	Vertical UP +	Pitch BOW UP +	Roll PORT UP +	Yaw COMPASS +
-1' Recessed inside hull	7125 TX	-1.767	-0.125	-3.289	0.60	1.04	1.00
	7125 RX (200 kHz)	-1.567	-0.125	-3.313			
	7125 RX (400 kHz)	-1.587	-0.125	-3.313			
0' Flush with hull	7125 TX	-1.767	-0.125	-3.594	0.60	1.04	1.00
	7125 RX (200 kHz)	-1.567	-0.125	-3.618			
	7125 RX (400 kHz)	-1.587	-0.125	-3.618			
3' Extended below hull	7125 TX	-1.767	-0.125	-4.508	0.60	1.04	1.00
	7125 RX (200 kHz)	-1.567	-0.125	-4.532			
	7125 RX (400 kHz)	-1.587	-0.125	-4.532			
6' Extended below hull	7125 TX	-1.767	-0.125	-5.423	0.60	1.04	1.00
	7125 RX (200 kHz)	-1.567	-0.125	-5.447			
	7125 RX (400 kHz)	-1.587	-0.125	-5.447			
POS-MV IMU		0.00	0.00	0.00	0.00	0.00	0.00
POS-MV GPS Antenna – Primary – STBD		4.947	1.940	15.792	-	-	-
POS-MV GPS Antenna – Secondary - PORT		4.980	-1.804	15.795	-	-	-
Waterline		-	-	-0.48	-	-	-

Table 3. Hypack configuration of sensor offsets after system geometry review and calibration during HRS1602. These values reflect the offsets in Table 2 translated into the Hypack reference frame, which takes its vertical reference from waterline and treats downward as positive. Because no new waterline measurement was made during HRS1602, the previous waterline value of 0.48 m below the IMU was maintained. New waterline measurements should be made to update the waterline value in Table 2 and the Hypack vertical reference. For example, if a new waterline measurement of 0.50 m is recorded (e.g., using clear plastic tubing from a through-hull valve near the IMU, as documented in 2012), the difference of 0.02 m (0.50 m new height of IMU above waterline minus the 0.48 m original measurement) should be subtracted from the existing vertical measurements in Hypack. Thus, the IMU height in Hypack would become -0.048 m – 0.02 m = -0.50 m for all drop keel positions. In this hypothetical example, the 7125 vertical offsets for the 3' drop keel positions would become 4.028 m – 0.02 m = 4.008 m, and so on for the other drop keel positions. This table should be updated whenever new waterline measurements are available. Under the existing data collection setup, the angular offsets should be entered for the Reson transducer in the Hypack configuration prior to data acquisition. Alternatively, data recorded using the Reson software directly (without Hypack) can be adjusted using these angular offsets in post-processing. It was observed that Hypack HSX files correctly preserved the angular offset configuration for post-processing, whereas HSX.s7k files logged in Hypack and native s7k files logged in the Reson software did not.

| Drop Keel	Sensors in HYPACK frame Origin at IMU	Alongship BOW +	Athwartship STBD +	Vertical DOWN +	Pitch BOW UP +	Roll PORT UP +	Yaw COMPASS +
-1' Recessed inside hull	7125 Reference Point	-1.767	-0.125	2.809	0.60	1.04	1.00
	IMU	0.00	0.00	-0.48	0.00	0.00	0.00
0' Flush with hull	7125 Reference Point	-1.767	-0.125	3.114	0.60	1.04	1.00
	IMU	0.00	0.00	-0.48	0.00	0.00	0.00
3' Extended below hull	7125 Reference Point	-1.767	-0.125	4.028	0.60	1.04	1.00
	IMU	0.00	0.00	-0.48	0.00	0.00	0.00
6' Extended below hull	7125 Reference Point	-1.767	-0.125	4.943	0.60	1.04	1.00
	IMU	0.00	0.00	-0.48	0.00	0.00	0.00
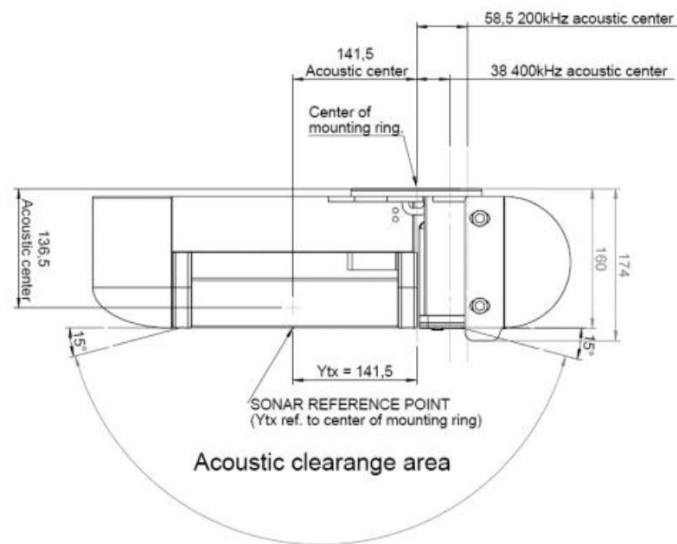
Figure 2. Schematic of a Reson 7125 SVP2 viewed from starboard (Reson SeaBat 7125 Operator Manual, v. 3, p. 179). The acoustic center of the TX array is taken as the sonar reference point, and frequency-specific offsets for the receiver are handled by specifying the SVP2 bracket in configuration. Data processed in Caris should use a vessel configuration file treating the sonar reference point as the Transducer 1 location. In QPS Qimera software testing, the HSX files logged with Hypack successfully preserved the array offsets to populate the Qimera vessel configuration.

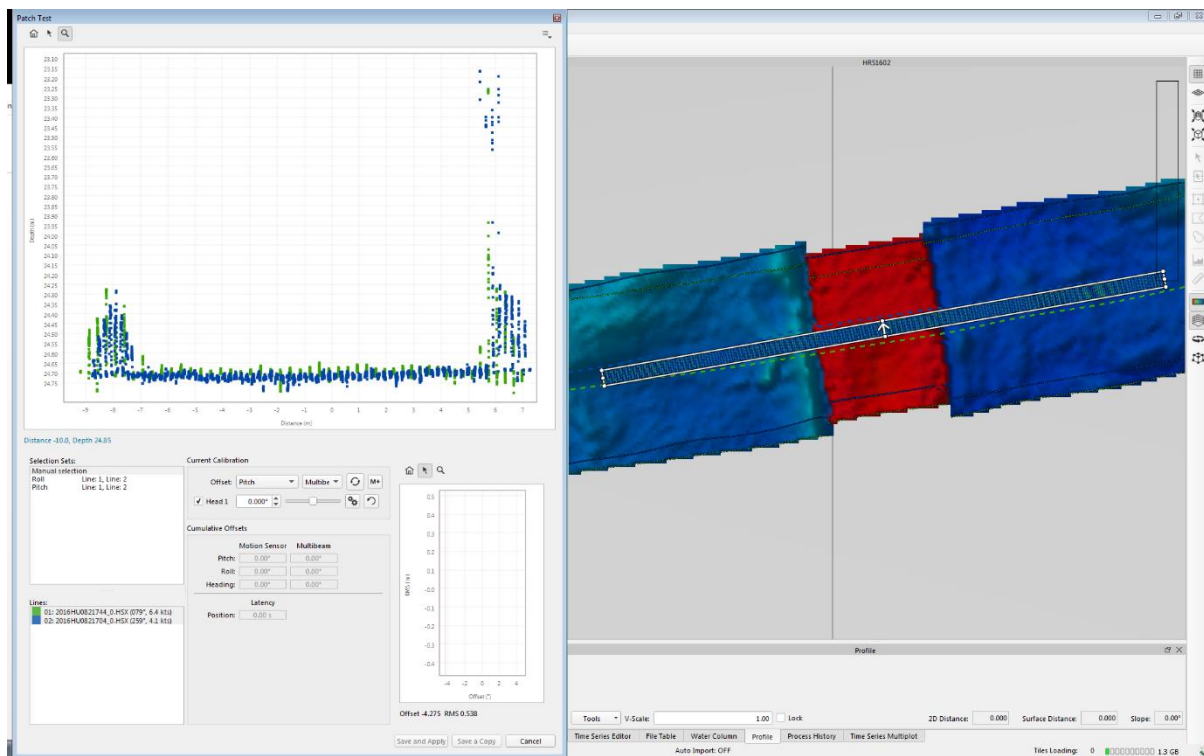## Calibration Subsets for Reson 7125 with POS-MV

Figure 3. Pitch calibration in Qimera using a subset of soundings on the barge top, showing alignment of railings mapped at nadir on opposite headings. The pitch adjustment of +0.60° is recorded in the Qimera vessel parameters (0.00° further adjustment in this calibration tool screenshot).
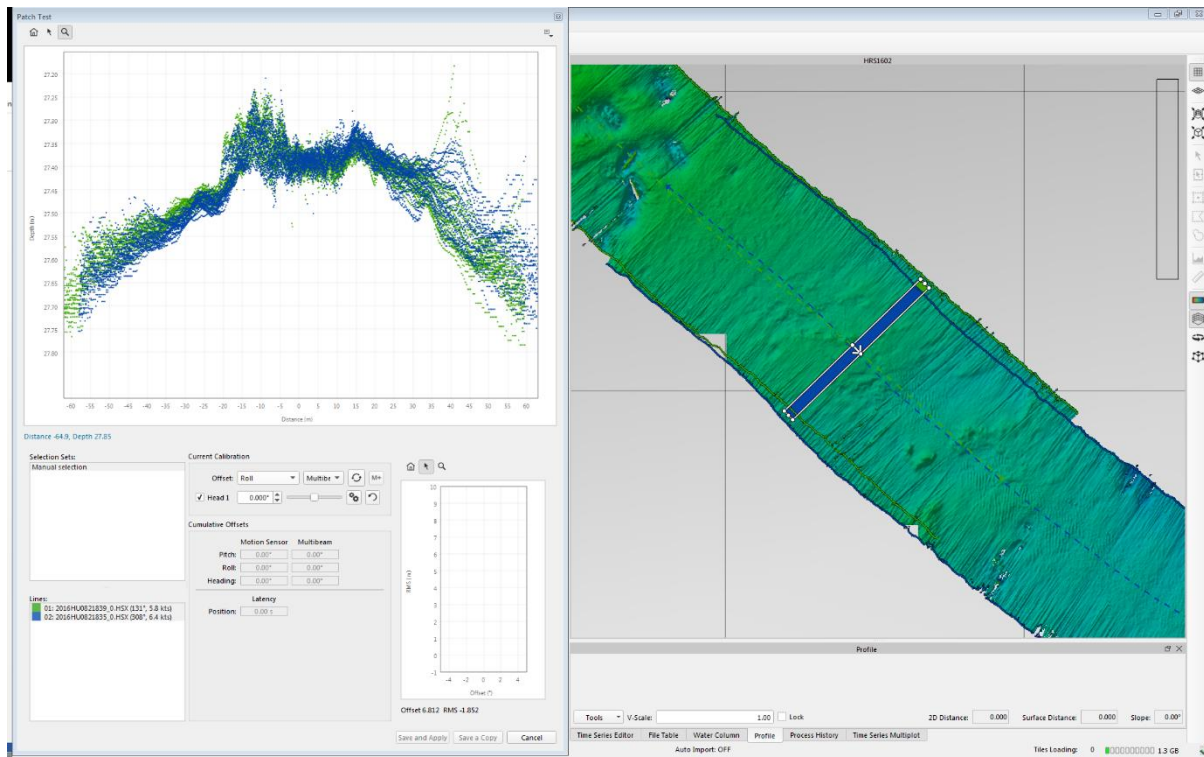
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Figure 4. Roll calibration in Qimera using a subset of soundings collected on opposite headings over relatively flat seafloor. The roll adjustment of +1.04° is recorded in the Qimera vessel parameters (0.00° further adjustment in this calibration tool screenshot).
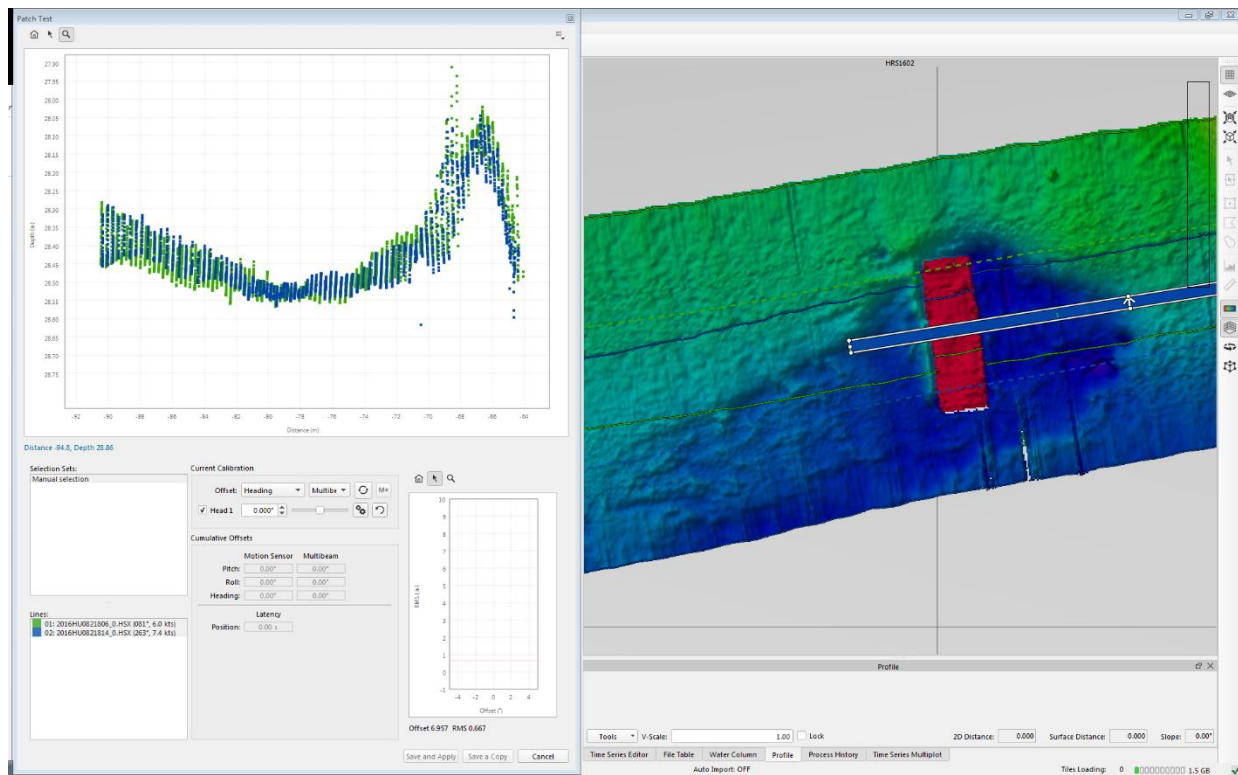

Figure 5. Yaw calibration in Qimera using soundings collected over sediment piled up due to clockwise barge rotation during a recent nor'easter. The yaw adjustment of +1.00° is recorded in the Qimera vessel parameters (0.00° further adjustment in this calibration tool screenshot).

Principal Findings & Recommendations

- The Reson 7125 was successfully calibrated using the POS-MV motion sensor and existing software configurations. The depths and features available for patch testing limited the angular resolution achievable for the calibration results, in that small angular differences are not exaggerated by depth. Regardless, the angular offsets determined during HRS1602 closely match previous results and differed appreciably for only the roll offset. All results are well within normal patch test ranges and were attributed entirely to the transducer installation within the vessel reference frame. A patch test must be performed after each removal and reinstallation of the 7125 or if any sensors are modified.

- The POS-MV IMU is rigidly mounted in an engineering space with ample cooling. Based on experience aboard other vessels, it is strongly recommended that the IMU and its cable be properly labeled with warning messages to avoid inadvertent human contact or impact. A rigid wire mesh 'cage' is common aboard other vessels and would provide extra protection from accidental stresses on the IMU, its cable, or its mount, all of which would detrimentally affect multibeam performance and lead to delays for additional patch testing.

- The next vessel survey performed should resolve the IMU angular offsets, after which these values can be entered in the Applanix configuration and a new patch test can be performed. Updated IMU-specific angular offset could potentially reduce the effect of coupling of the individual angular offsets between the IMU and transducer installation. This is not a critical issue for the mapping system, but should be addressed with a full vessel survey (treating the IMU as the origin) during the next major dry-dock period or midlife refit.

- The drop keel bolt spacing is in whole yards, not meters. All vertical offset documentation in units of 'meters' should be double-checked to ensure that the numerical values correspond to spacing of 1 yd rather than 1 m.

- Screenshots of post-HRS1602 Reson, Hypack, and Applanix configurations are included separately. Please contact the MAC if any discrepancies are found or modifications are made to the configurations which can be documented with additional screenshots.

- It was noted during HRS1602 post-processing that Hypack HSX files opened in Qimera had correctly preserved the angular offsets entered under the HYSWEEP Survey parameters for the SeaBat 7125 installation, whereas Hypack HSX.s7k files were much larger and did not properly preserve the offsets. Thus, post-processing HSX files in Qimera should not require any further adjustment of offsets assuming these (especially vertical for each drop keel position) are properly entered in HYSWEEP Survey parameters prior to data collection. Other processing paths may require careful application of the offsets (again, especially vertical for each drop keel position) in vessel parameters. A set of Caris vessel files with offsets for each frequency and drop keel depth are under development.

- UDEL personnel are presently configuring a new computer with massive storage capability for water column logging with the Reson 7125. While the existing configuration with Hypack running on the Reson machine proved stable during HRS1602, the stability of this arrangement has been discussed as a complication during previous mapping cruises. The MAC recommends moving the Hypack installation to the new water column logging machine, as this practice of separating the multibeam and logging/planning software is common aboard other vessels to help improve stability of Hypack operation and minimize data loss when crashes occur. A sheet of recommendations for water column configuration was provided by V. Pradith of Hypack, available at ftp://ftp.hypack.com/Documents/SoundingBetterArchives/2014/wcHysweep%20Beta.pdf. The MAC is available to help in any way it can with setup of this water column logging capability.

- The Sharp is the only UNOLS vessel visited by the MAC which using a non-Kongsberg multibeam echosounder; thus, the tools developed by the MAC to evaluate system noise, swath coverage, and accuracy achieved by other installations are not readily applied to the data collected aboard the Sharp.

- Even with the drop keel at 3' below the hull, bubble sweep plagued the multibeam data when heading into a swell during HRS1602. Increased acoustic attenuation and noise due to bubble sweep is an extremely common issue on flush-mounted multibeam installations but is typically remedied with such drop keels and transducer gondola designs by extending the acoustic sensing faces beyond the mixed bubbly layer. Any upcoming mid-life vessel refit projects should strongly consider hull modifications to reduce aeration at the bow and improve bubble diversion away from centerline of the hull.

- As a whole, the multibeam system is in satisfactory working condition despite the bubble sweep issue and we do not anticipate any obvious issues for the 2016 mapping season. All documentation of system offsets and angles should be maintained and updated carefully as sensor configurations change, in tandem with documentation for future patch tests. Additional calibration lines in deeper water, collected on an opportunistic basis, can be forwarded to the MAC for verification of the angular offsets documented in this report.