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Data Acquisition & Processing Report

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LOCALITY

State *New York and New Jersey*

General Locality *Lower New York Harbor*

2013 − 2014

CHIEF OF PARTY

Gary R. Davis
Leidos

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Data Acquisition & Processing Report

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ACRONYMS

Acronym	Definition
ACD	**A**utomatic **C**ontact **D**etection
AHB	**A**tlantic **H**ydrographic **B**ranch
ASCII	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange
BAG	**B**athymetric **A**ttributed **G**rid
CI	**C**onfidence **I**nterval
CMG	**C**ourse **M**ade **G**ood
CTD	**C**onductivity, **T**emperature, **D**epth profiler
CUBE	**C**ombined **U**ncertainty and **B**athymetric **E**stimator
DAPR	**D**ata **A**cquisition and **P**rocessing **R**eport
DGPS	**D**ifferential **G**lobal **P**ositioning **S**ystem
DPC	**D**ata **P**rocessing **C**enter
DR	**D**escriptive **R**eport
ECDIS	**E**lectronic **C**hart **D**isplay and **I**nformation **S**ystem
EPF	**E**rror **P**arameters **F**ile
Ft	**F**ee**t**
GPS	**G**lobal **P**ositioning **S**ystem
GSF	**G**eneric **S**ensor **F**ormat
HDCS	**H**ydrographic **D**ata **C**leaning **S**ystem
HSSD	NOS **H**ydrographic **S**urveys **S**pecifications and **D**eliverables
Hp	**H**orse **p**ower
Hz	**H**ert**z**
IHO	**I**nternational **H**ydrographic **O**rganization
IMU	**I**nertial **M**easurement **U**nit
ISO	**I**nternational **O**rganization for **S**tandardization
ISS-2000	**I**ntegrated **S**urvey **S**ystem 2000
ISSC	**I**ntegrated **S**urvey **S**ystem **C**omputer
JD	**J**ulian **D**ay
kHz	**k**ilo**H**ert**z**
kW	**k**ilo**W**att
LOA	**L**ength **O**ver **A**ll
MVE	**M**ulti-**V**iew **E**ditor
MVP	**M**oving **V**essel **P**rofiler
NAS	**N**etwork **A**ttached **S**torage
NJ	**N**ew **J**ersey
NMEA	**N**ational **M**arine **E**lectronics **A**ssociation
NOAA	**N**ational **O**ceanic and **A**tmospheric **A**dministration
NOS	**N**ational **O**cean **S**ervice
NY	**N**ew **Y**ork
ONSWG	**O**pen **N**avigation **S**urface **W**orking **G**roup
PFM	**P**ure **F**ile **M**agic
POS/MV	**P**osition **O**rientation **S**ystem/**M**arine **V**essels
QA	**Q**uality **A**ssurance
QC	**Q**uality **C**ontrol

RI	**R**hode **I**sland
RPM	**R**evolutions **P**er **M**inute
SABER	**S**urvey **A**nalysis and area **B**ased **E**dito**R**
SAT	**S**ea **A**cceptance **T**ests or **S**wath **A**lignment **T**ool
SSP	**S**ound **S**peed **P**rofile
SV&P	**S**ound **V**elocity and **P**ressure Sensor
TPE	**T**otal **P**ropagated **E**rror
TPU	**T**otal **P**ropagated **U**ncertainty or **T**ransceiver **P**rocessing **U**nit
TTL	**T**ransistor-**T**ransistor **L**ogic
UPS	**U**ninterruptible **P**ower **S**upply
UTC	**C**oordinated **U**niversal **T**ime
XML	e**X**tensible **M**arkup **L**anguage
XTF	e**X**tended **T**riton **F**ormat

PREFACE

This Data Acquisition and Processing Report (DAPR) applies to hydrographic sheets H12586 and H12587. Survey data were collected from August 2013 through January 2014. The GSF files delivered for sheets H12586 and H12587 are GSF version 03.04. CARIS HIPS and SIPS version 7.1 Service Pack 2 Hotfix 6 and later versions are compatible with GSF version 03.04.

For these surveys no vertical or horizontal control points were established, recovered, or occupied. Therefore, a Horizontal and Vertical Control Report is not required for these sheets, and will not be submitted with the final delivery of this project.

Data collection was performed according to the April 2013 version of the "*NOS Hydrographic Specifications and Deliverables*" (HSSD) as specified in the Hydrographic Survey Project Instructions dated 23 May 2013. Additional project specific clarifications and guidance are located in Appendix II of the Descriptive Report (DR) for each sheet.

A. EQUIPMENT

A.1 DATA ACQUISITION

Central to the Leidos survey system was the Integrated Survey System Computer (ISSC). The ISSC consisted of a quad core processor computer with the Windows XP (Service Pack 2) operating system, which ran the Leidos Integrated Survey System 2000 (**ISS-2000**) software. This software provided survey planning and real-time survey control in addition to data acquisition and logging for side scan, bathymetry, and navigation data. An Applanix Position and Orientation System for Marine Vessels (POS/MV) and Inertial Measurement Unit (IMU) were used to provide positioning, heave, and vessel motion data during these surveys. Klein side scan sonar data were acquired using Klein's **SonarPro** software running on a computer with the Windows XP (Service Pack 2) operating system.

A.2 DATA PROCESSING

Post-acquisition singlebeam, multibeam, and side scan data processing were performed on the survey vessel, in the Middletown, NJ, Field Office, and in the Newport, RI, Data Processing Center (DPC). Singlebeam, multibeam, and side scan data were processed on computers with the Linux operating system, which ran the Leidos **SABER** (Survey Analysis and Area Based EditoR) software. Subsequently, within **SABER**, side scan mosaics were created and side scan contacts were correlated with multibeam data. In the Middletown, NJ Field Office, data were stored locally on the processing computers, and on archive hard drives separate from the operating system, which were networked for access by all computers. Onboard the *M/V Atlantic Surveyor* and in the Newport, RI DPC data were stored on a Network Attached Storage (NAS) system that all computers were able to access.

A.3 SURVEY VESSELS

For this project, Leidos employed three survey vessels each with the following data acquisition systems for the survey effort:

- The *M/V Atlantic Surveyor* used a RESON 7125 SV multibeam sonar, a towed Klein 3000 dual frequency side scan sonar, and a Brooke Ocean Technology Moving Vessel Profiler 30 (MVP-30).
- The *R/V Oyster Bay* used an Odom Echotrac CVM singlebeam sonar, bow mounted Klein 3000 dual frequency side scan sonar, and an SBE 19-01 CTD for data collection. For item investigations a RESON 8101 ER multibeam sonar was installed.
- The *R/V Henry Hudson* used a RESON 8101 ER multibeam sonar, a bow mounted Klein 3900 side scan sonar, and an SBE 19-01 CTD for data collection. A Klein 3000 dual frequency side scan sonar was installed after a failure of the Klein 3900.

All vessels used a POS/MV 320 version V4 for vessel attitude and positioning. Table A-1 presents the characteristics for all three vessels. Further details about the vessels, acquisition systems and software, and processing software are provided in the sections below.

Table A-1. Survey Vessel Characteristics; *M/V Atlantic Surveyor*, *R/V Oyster Bay*, and *R/V Henry Hudson*

Vessel Name	LOA (Ft)	Beam (Ft)	Draft (Ft)	Max Speed	Gross Tonnage	Power (Hp)	Registration Number
M/V Atlantic Surveyor	110	26	9.0	14 knots	Displacement 68.0 Net Tons Deck Load 65.0 Long Tons	900	D582365
R/V Oyster Bay	30	9	3.0	40 knots	Displacement 10,000lbs	400	NJ3979HF
R/V Henry Hudson	45	16	3.2	24 knots	Displacement 39,000lbs	715	1152452

The *M/V Atlantic Surveyor* (Figure A-1) was equipped with an autopilot, echo sounder, Differential Global Positioning System (DGPS), radars, and two 40 kilowatt (kW) diesel generators. Accommodations for up to twelve surveyors were available within three cabins. The side scan winch and three 20-foot International Organization for Standardization (ISO) containers were secured on the aft deck. The first container was used as the real-time survey data collection office, the second container was used for the data processing office, and the third container was used for spares storage, maintenance, and repairs. A fourth 10-foot ISO container was also mounted on the aft deck which housed an 80 kW generator that provided dedicated power to the side scan winch, ISO containers, and all survey equipment. The POS/MV IMU was mounted approximately amidships, below the main deck, port of the keel. The RESON 7125 SV transducer and RESON SVP 70 surface sound velocity sensor were hull-mounted approximately amidships, port of the vessel’s keel. A Brooke Ocean Technology Moving Vessel Profiler 30 (MVP-30) was mounted on the starboard stern quarter. Configuration parameters, offsets, and installation diagrams for all equipment are included in Section C of this report.

Figure A-1. The *M/V Atlantic Surveyor*

The *R/V Oyster Bay* (Figure A-2) was equipped with an autopilot, echo sounder, Differential Global Positioning System (DGPS), radar, and a 6.5 kilowatt (kW) gas generator. The side scan was bow mounted. The POS/MV IMU was mounted in the bow port of the keel. An ODOM Echotrac CVM singlebeam sonar was pole mounted on the port side. Configuration parameters, offsets, and installation diagrams for all equipment are included in Section C of this report. On 20 November 2013, (JD 325) the ODOM singlebeam system was replaced with a RESON 8101 ER.

Figure A-2. The *R/V Oyster Bay*

The *R/V Henry Hudson* (Figure A-3) was equipped with an autopilot, echo sounder, Differential Global Positioning System (DGPS), radar, and a 12 kilowatt (kW) diesel generator. The side scan was bow mounted. The POS/MV IMU was mounted approximately centerline amidships, below the main deck. A RESON 8101 ER multibeam sonar was pole mounted on the port side. Configuration parameters, offsets, and installation diagrams for all equipment are included in Section C of this report.

Figure A-3. The *R/V Henry Hudson*

A.4 SINGLEBEAM SYSTEMS AND OPERATIONS

An Odom Echotrac CVM singlebeam sonar was installed on the *R/V Oyster Bay*. The **ISS-2000** software provided navigation, system control, and collected the singlebeam data in Generic Sensor Format (GSF).

Confidence checks of the singlebeam depths were made using a bar that was lowered to a known depth directly below the transducer. Depths displayed by the Odom controller and **ISS-2000** system were verified and entered into a bar check log. The following procedure was established to perform a bar check comparison:

1. Take and apply a CTD cast.
2. Set the Odom draft to 0.0 meters in **ISS-2000**.
3. Disable the tide corrector.
4. Set RPM value to 0.00 **ISS-2000**.
5. Set the bar to 1 meter under the transducer.
6. Verify that the tide corrector in the MB Manager window is 0 meters and the depth corrector is 0 meters.
7. Open the sbcdtc.exe Video32 display from the task bar.
8. Open the ODOMCV DTC Display. Verify tide correct is 0 meters, transducer offset is 0 meters, and applied squat is 0 meters.
9. In the Odom Controller window go to the calibrate tab and enter the bar depth.
10. Enter the time, bar depth, depth in the video 32 display, ODOM CV DTC display, and the channel 1 depth in the Odom Controller.
11. In the MB Manager display select Display/Examine Data and look at the last depth values in the recorded file. Also verify tide and depth correctors in the file are 0 meters.
12. Set the bar to 2 meters and repeat steps 9 through 11 changing the bar depth in the Odom controller calibrate window to 2 meters.
13. Repeat at 1 meter intervals for as deep as possible.

Bar checks were taken approximately once per week during the survey. Bar check results are included with the survey data in Section I of the Separates of each sheet's Descriptive Report.

In addition, confidence checks of the singlebeam system were made by comparing the depth data collected over a common survey line which were run simultaneously by all three survey vessels. For these comparisons the *R/V Oyster Bay* would rendezvous with the *R/V Henry Hudson* and/or the *M/V Atlantic Surveyor*, the vessels would take and apply individual SSP casts, and then proceed to acquire data over a common survey line; one vessel immediately following the other to reduce any tidal or environmental differences.

Multiple survey vessel comparisons were performed periodically during the survey throughout the timeframe that two or more survey vessels were in operation.

Confidence checks from the Sea Acceptance Test (SAT) of the *R/V Oyster Bay* as well as those during the made during the survey all showed good comparison of the singlebeam system with the multibeam systems.

The results of a bar check comparison performed on the singlebeam system 13 September 2013 (JD 256) showed a difference of approximately 0.010m between bar depth and observed singlebeam depth value. Extensive investigation of the singlebeam system showed that a drift had occurred in the singlebeam transducer index constant. The cause of the drift was not specifically identifiable, though there were many factors from the survey operations that could have contributed to this, the most probable being the when the singlebeam transducer struck a submerged wreck on 25 August 2013 (JD 237).

To compensate for the observed offset in the bar check depths, an index value of 0.011m was entered into the Odom controller on 18 September 2013 (JD 261). Once this index value was set, bar check comparisons and confidence checks between multiple survey vessels were performed, all showed good comparisons with the singlebeam system. Watchstander procedures were then put in place to ensure this index value was not changed, and confidence checks showed good comparison, with this value in place, through the completion of singlebeam survey operations.

A.5 LIDAR SYSTEMS AND OPERATIONS

Leidos did not use a lidar system on this survey.

A.6 MULTIBEAM SYSTEMS AND OPERATIONS

The real-time multibeam acquisition system used for these surveys included each of the following unless otherwise specified:

- Windows XP workstation (ISSC) for data acquisition, system control, survey planning, survey operations, and real-time Quality Control (QC).

- RESON SeaBat 7125 SV multibeam system with a SVP 70 sound speed sensor (see Appendix IV for the SVP 70 calibration reports) was installed onboard the *M/V Atlantic Surveyor*. The RESON 7125 SV is a single frequency system operating at 400 kHz. It has three beam configurations: 256 Equi-Angular, 512 Equi-Angular, or 512 Equi-Distant beams. In all configurations the beams are dynamically focused resulting in a 0.5 degree across-track receive beam width and a 1.0 degree along-track transmit beam width with a 130 degree swath (65 degrees per side). The RESON 7125 SV was set to the 256 beams Equi-Angular mode during survey operations. The maximum ping rate was manually set to 15 hertz, except during item investigations when the maximum ping rate for the selected range was used. By manually setting the ping rate, the size of the GSF files remained manageable while still ensuring adequate bottom coverage. Item investigation data using the RESON 7125 SV were collected at slower speeds, generally four to six knots, and if necessary utilized the 512 beams Equi-Distant mode or Beam Compression mode at the maximum achievable ping rate for the range selected. As a result, all significant features met the object detection requirements as defined in Section 5.2.2.1 of the HSSD, unless otherwise specified in a sheet's Descriptive Report (DR).

RESON SeaBat 7125 SV	
Firmware	**Version/SN**
7-P Sonar Processor	1812005
400 KHz Projector	4709011
EM7216 Receive Array	22010031
7k Upload Interface	3.12.7.3
7k Center	3.7.11.11
7k I/O	3.4.1.11
RESON SVP 70 SSV sensor	203030

- RESON SeaBat 8101 ER multibeam system was installed onboard the *R/V Henry Hudson* and later installed onboard the *R/V Oyster Bay* during holiday and item investigation survey operations. The RESON SeaBat 8101 ER is a 240 kilohertz (kHz) system with 101 beams. Beams are 1.5 degrees along track and 1.5 degrees across track with a 150 degree swath (75 degrees per side). Range scale and ping rates are user selectable. The ping rate was set to a maximum of 40 pings per second and was regulated by the range scale selected. The multibeam range scale was selected by the operator to yield the highest ping rate while maintaining a 120 degree usable swath (60 degrees per side). The range scale was selected based on water depth and was maintained at or below a range scale of 50 meters. The maximum 50-meter range scale or less was used in order to meet the requirement that 95% of all nodes of the final depth surface are populated with at least three soundings, Section 5.2.2.2 of the April 2013 HSSD, while maintaining an efficient survey speed. To meet this requirement, the survey speed was typically maintained below 5.7 knots while using a maximum multibeam range scale of 50 meters to ensure at least 95% of all nodes on the surface are populated with at least three soundings. While operating at multibeam range scales below 50 meters, the maximum survey speed was constrained by the side scan range scale settings, and is discussed in greater detail in the Side scan Sonar Systems and Operations (Section A.7) of this report.

RESON SeaBat 8101	
Firmware	**Version/SN**
8101 Dry End	2.09-E34D
8101 Wet End	1.08-C215

- POS/MV 320 Position and Orientation System Version 4 with a Trimble ProBeacon Differential Receiver (Serial Number 2201896953) was installed onboard the *M/V Atlantic Surveyor*.

POS/MV 320	
System	**Version/Model/SN**
MV-320	Ver4
SERIAL NUMBER	S2575
HARDWARE	2.9-7
FIRMWARE	5.08
ICD	5.02
OPERATING SYSTEM	425B14
IMU TYPE	2
PRIMARY GPS TYPE	BD950
SECONDARY GPS TYPE	BD950
DMI TYPE	DMI0
GIMBAL TYPE	GIM0
OPTION 1	THV-0

- POS/MV 320 Position and Orientation System Version 4 with a Trimble ProBeacon Differential Receiver (Serial Number 220159406) was installed onboard the *R/V Oyster Bay*.

POS/MV 320	
System	**Version/Model/SN**
MV-320	Ver4
SERIAL NUMBER	S2579
HARDWARE	2.9-7
FIRMWARE	5.08
ICD	5.02
OPERATING SYSTEM	425B14
IMU TYPE	2
PRIMARY GPS TYPE	BD950
SECONDARY GPS TYPE	BD950
DMI TYPE	DMI0
GIMBAL TYPE	GIM0
OPTION 1	THV-0

- POS/MV 320 Position and Orientation System Version 4 with a Trimble ProBeacon Differential Receiver was installed onboard the *R/V Henry Hudson*.

POS/MV 320	
System	**Version/Model/SN**
MV-320	Ver4
SERIAL NUMBER	S2103
HARDWARE	2.6-6
FIRMWARE	5.08
ICD	5.02
OPERATING SYSTEM	425B14
IMU TYPE	2
PRIMARY GPS TYPE	BD950
SECONDARY GPS TYPE	BD950
DMI TYPE	DMI0
GIMBAL TYPE	GIM0
OPTION 1	THV-0

- Trimble 7400 DSi GPS Receiver (Serial Number 3815A22469) with a Furuno Differential Receiver (3506-7687) (secondary positioning sensor) was installed onboard the *M/V Atlantic Surveyor*.
- Trimble SPS351 GPS Receiver (4948D3009) with built in Differential Receiver (secondary positioning sensor) was installed onboard the *R/V Oyster Bay*.
- Hemisphere GPS Receiver with built in Differential Receiver (secondary positioning sensor) was installed onboard the *R/V Henry Hudson*.
- MVP 30 Moving Vessel Profiler with interchangeable Applied Microsystems Smart Sound Velocity and Pressure (SV&P) Sensors and a Notebook computer to interface with the ISSC and the deck control unit (See Section A.8 for additional details concerning sound speed and Appendix IV for the SV&P Sensor calibrations). This system was installed onboard the *M/V Atlantic Surveyor*.

MVP 30	
System	**Version/Model/SN**
MVP	30
Software	2.21
SV&P Sensors	4523 4880 5332 5454 5455

- Seabird Model SBE 19 Conductivity, Temperature, Depth (CTD) profiler

SBE CTD	
System	**Version/SN**
SBE-19	193607-0565 194275-0648 1920459-2710
Software	1.55

- Monarch shaft RPM sensors (onboard the *M/V Atlantic Surveyor* only).
- Notebook computer for maintaining daily navigation and operation logs.
- Uninterrupted power supplies (UPS) for protection of the entire system.

Leidos maintains the ability to decrease the usable multibeam swath width for the RESON systems as necessary to maintain data quality and meet the required IHO specifications, however, if this ability was exercised, the usable multibeam swath width was always maintained above 90 degrees (45 degrees per side). During data collection, swath data were flagged as either class one to 10 degrees (5 degrees per side) or class two from 90 to 120 degrees (45 to 60 degrees per side). Swath data flagged as class one or class two were used for grid generation while data outside of class two were flagged as ignore but were retained for potential future use. Beam Compression was also possible with the RESON 7125 SV multibeam system during real-time data acquisition. If Leidos utilized the RESON 7125 SV multibeam system Beam Compression capabilities, it was done for item investigations in order to acquire concentrated multibeam data over seafloor features. If utilized, Beam Compression values were always set above 90 degrees (45 degrees per side).

The resultant achievable multibeam bottom coverage was controlled by the set survey line spacing and the various water depths within the survey areas. The survey line spacing was 20 or 40 meters for use with a side scan range setting of 25 meters (30 meters for the Klein 3900) in depths approximately between 2 and 6 meters. The survey line spacing was 40 meters for use with a side scan range setting of 50 meters in depths approximately greater than 6 meters.. Using ±60 degrees as the acceptable swath, 100 percent multibeam coverage was achieved in depths deeper than approximately 15 meters using 40-meter line spacing.

All multibeam or singlebeam data and associated metadata were collected and stored on the real-time survey computer (ISSC) using a dual logging architecture. This method ensured a copy of all real-time data files were logged to separate hard drives during the survey operations. On the *M/V Atlantic Surveyor* these files were archived to the on-board NAS for initial processing and quality control review at the completion of each survey line. On the *R/V Oyster Bay* and *R/V Henry Hudson* these files were archived to an external hard drive which was used to transfer data to the field processing office at the end of each survey day. The field processing office conducted the initial processing and quality control review the following day.

File names were changed at the end of each line. This protocol provided the ability to easily associate each consecutive multibeam or singlebeam GSF file number ".dXX" with a specific survey line. However, due to software restrictions within **ISS-2000**, there is a limitation of 99 consecutive ".dXX" files per Julian Day (JD). Therefore, when survey operations would potentially result in more than 99 survey lines per day, such as holiday fills and/or item investigations, groups of multiple survey lines of the same type were collected to the same GSF file. In all cases, main scheme and crossline data were collected in separate GSF files.

If a file was not manually changed between survey lines, the multibeam GSF file was typically split later during post processing. This procedure utilized the **SABER** command line program **gsfsplit**. This program provided the ability to split GSF files so that each survey line was unique to a single multibeam or singlebeam GSF file or set of files.

When a multibeam or singlebeam file needed to be split, a copy of the original GSF file was made and the **gsfsplit** program was then run on the copied file. Using the ping flags stored in the GSF file, **gsfsplit** splits the file midway through the offline pings between survey lines. Each newly created file resulting from the splitting process was given a new ".dXX" sequential file number extension. When assigning new ".dXX" extensions to the newly created files, the program starts with ".d99". The sequential file number extension is then consecutively incremented backwards for each new file created (i.e. ".d99", ".d98", ".d97", etc). These high file number extensions were chosen to ensure that there would never be an occurrence of multiple GSF files containing the same name. Once the file split process was complete, the newly created files were manually renamed in the following manner: the first survey line was given the extension from the original split file and each subsequent survey line was assigned the highest available ".dXX" file number extension (i.e. original file.d01 would result in file.d01 and file.d99 after being split).

GSF file lists were updated to include the split files which were placed in chronological order (not numerical order). All file splits were documented in the "Multibeam Processing Log" provided in Separates I of each sheet's Descriptive Report.

At the end of each survey day all raw real-time data files from the day were backed-up to digital magnetic tape from the hard drives of the ISSC machine. All processed data on the field office processing computers were backed-up to an external hard drive and digital magnetic tape approximately every week. The external hard drive and the digital magnetic tape back-ups were shipped during port calls (approximately every week) to the Leidos DPC in Newport, RI for final processing and archiving.

Leidos continuously logged multibeam or singlebeam data throughout survey operations collecting all data acquired during turns and transits between survey lines. Leidos utilized ping flags within the GSF files to differentiate between online/offline data. Online data refers to the bathymetry data within a GSF file which were used for generating the Combined Uncertainty and Bathymetric Estimator (CUBE) Depth surface.

See Section B.2.7 for a detailed description of multibeam ping and beam flags. Information regarding the start and end of online data for each survey line is found in the "Watchstander Logs" and "Side scan Review Log" that are delivered in Separates I of each sheet's Descriptive Report.

Lead line comparisons were conducted to provide Quality Assurance (QA) for the RESON 7125 SV and the RESON 8101 ER multibeam systems. These confidence checks were conducted in accordance with Section 5.2.3.1 of the HSSD and were made approximately every seven survey days.

Lead line comparison confidence checks were performed as outlined in the following steps:

- The static draft of the survey vessel was measured immediately prior to the beginning of the comparison. The value was entered into the **ISS-2000** real-time parameters for the multibeam (see Section C.1.1 of this report for a detailed description of how static draft is measured).
- Correctors to the multibeam data, such as real-time tides and dynamic draft, were disabled in the **ISS-2000** system.
- A new sound speed profile was taken and applied to the multibeam data.
- A digital watch was synchronized to the time of the **ISS-2000** data acquisition system in order to accurately record the time for each lead line depth observation made on the *M/V Atlantic Surveyor* with the RESON 7125 SV multibeam system. The times of each lead line depth observation were marked directly from the **ISS-2000** system for the *R/V Oyster Bay* and *R/V Henry Hudson* with the RESON 8101 ER multibeam system.
- For the *M/V Atlantic Surveyor* with the RESON 7125 SV multibeam system ten depth measurements were acquired on each side of the vessel at the location of the multibeam transducer using a weighted tape measure. For the *R/V Oyster Bay* and *R/V Henry Hudson* with the RESON 8101 ER multibeam system ten depth measurements were acquired at the center of the multibeam transducer.
- The current Julian Day, date, vessel draft value, the multibeam data file(s), and the sound speed profile file were entered in the "Lead Line Comparison Log" (Figure A-4) (Separates I).
- The observed time and depth of each lead line measurement were entered in the "Lead Line Comparison Log".
- The concurrent multibeam depth measurements recorded in the GSF file were then entered in the "Lead Line Comparison Log".

Lead line depth measurements were made using a mushroom anchor affixed to a line and a tape measure (millimeter resolution). The measurements taken provide the distance from the seafloor to a reference mark on either the transducer pole mount (for the *R/V Oyster Bay* and *R/V Henry Hudson*) or to the top of a 0.02 meter square metal bar protruding from the port and starboard sides main deck (for the *M/V Atlantic Surveyor*). At least ten separate depth measurements and corresponding times are recorded for both the port and starboard sides of the *M/V Atlantic Surveyor*. And, at least ten separate depth measurements and corresponding times were recorded for transducer pole reference mark of the *R/V Oyster Bay* and the *R/V Henry Hudson*. The measurements were recorded into the spreadsheet which uses the static draft measurement to calculate the water depth.

Once all lead line measurements and times have been recorded in the lead line spreadsheet, the Leidos **ExamGSF** program is used to view the data within the multibeam GSF file which was logged concurrently. The depth value recorded in the multibeam file at the time of each lead line measurement and at the appropriate across track distance from nadir was entered into the appropriate column and row of the lead line spreadsheet. The lead line spreadsheet calculated the difference and standard deviation between the observed lead line measurements and the acoustic measurements from the multibeam system. Results of the lead line comparison were reviewed and if any differences or discrepancies were found, further investigation was conducted. Lead line results are included with the survey data in Section I of the Separates of each sheet's Descriptive Report.

LEADLINE COMPARISON	DRAFT ENTERED IN COMPUTER = 2.57		files
DAY 194	DRAFT ON HULL = 2.57	port	asmba13194.d02
DATE 07/12/13	SQUAT DEPTH CORRECTOR LEFT IN = 0.00	stbd	asmba13194.d02
	DRAFT CORRECTOR = 0.00	SVP	assvt12194.d01
	PORT DECK TO WATER SURFACE = 0.97		
	STBD DECK TO WATER SURFACE = 0.93	0.00	<=TIDE CORRECTOR LEFT IN

cast #	time taken port UTC	port deck to bottom meters	port cast depth meters	multibeam depth port (3.3m)	corrected multibeam depth port	time taken starboard UTC	stbd deck to bottom meters	stbd cast depth meters	multibeam depth starboard (4.2m)	corrected multibeam depth stbd	port difference meters	starboard difference meters
1	01:25:15	5.17	4.20	4.22	4.22	01:28:00	5.46	4.53	4.53	4.53	-0.020	0.000
2	01:25:20	5.20	4.23	4.26	4.26	01:28:05	5.47	4.54	4.50	4.50	-0.030	0.040
3	01:25:25	5.24	4.27	4.30	4.30	01:28:10	5.49	4.56	4.56	4.56	-0.030	0.000
4	01:25:30	5.22	4.25	4.26	4.26	01:28:15	5.51	4.58	4.61	4.61	-0.010	-0.030
5	01:25:35	5.22	4.25	4.28	4.28	01:28:20	5.54	4.61	4.64	4.64	-0.030	-0.030
6	01:25:40	5.19	4.22	4.23	4.23	01:28:25	5.58	4.65	4.63	4.63	-0.010	0.020
7	01:25:45	5.20	4.23	4.27	4.27	01:28:30	5.58	4.65	4.68	4.68	-0.040	-0.030
8	01:25:50	5.25	4.28	4.30	4.30	01:28:35	5.58	4.65	4.68	4.68	-0.020	-0.030
9	01:25:55	5.25	4.28	4.28	4.28	01:28:40	5.58	4.65	4.69	4.69	0.000	-0.040
10	01:26:00	5.21	4.24	4.27	4.27	01:28:45	5.58	4.65	4.68	4.68	-0.030	-0.030
										Mean	-0.022	-0.013
										StdDev	0.01229	0.02669

Figure A-4. *M/V Atlantic Surveyor* Example Lead Line Spreadsheet

In addition, confidence checks of the multibeam systems were made by comparing the depth data collected over a common survey line which were run simultaneously by multiple survey vessels. For these comparisons the *R/V Oyster Bay*, the *R/V Henry Hudson*, and/or the *M/V Atlantic Surveyor* would rendezvous to perform a multi-vessel comparison of the multibeam systems. The vessels would meet, take and apply individual SSP casts, and then proceed to acquire data over a common survey line; one vessel immediately following the other to reduce any tidal or environmental differences.

Multiple survey vessel comparisons were performed periodically during the survey throughout the timeframe that two or more survey vessels were in operation.

In accordance with the April 2013 *NOS HSSD* and the Project Instruction Leidos collected multibeam backscatter with all GSF data acquired by the RESON 7125 SV and RESON 8101 ER. The multibeam settings in use for each system were checked to ensure acceptable quality standards were met and to avoid any acoustic saturation of the backscatter data. The multibeam backscatter data acquired by each system was written to the GSF in real-time by **ISS-2000** and are delivered in the final GSF files for each sheet.

A.7 SIDE SCAN SONAR SYSTEMS AND OPERATIONS

These survey operations were conducted at set line spacing optimized to achieve 200% side scan sonar coverage in water depths greater than four meters and 100% side scan sonar coverage in water depths of two to four meters.

The side scan sonar systems used for these surveys included the following unless otherwise specified in the DR for each sheet:

On the *M/V Atlantic Surveyor:*

- A towed Klein 3000 digital side scan sonar towfish with a Klein K1 K-wing depressor.
- Klein Sonar workstation with Windows XP (Service Pack 2) for data collection and logging of side scan sonar data with Klein **SonarPro** software.
- Klein Transceiver Processing Unit.
- McArtney sheave with cable payout indicator.
- Sea Mac winch with remote controller.
- Uninterrupted power supplies (UPS) for protection of the entire system (except the winch).

On the *R/V Oyster Bay:*

- A bow mounted Klein 3000 digital side scan sonar towfish .
- Klein Sonar Workstation with Windows XP (Service Pack 2) for data collection and logging of side scan sonar data with Klein **SonarPro** software.
- Klein Transceiver Processing Unit.
- Uninterrupted power supplies (UPS) for protection of the entire system.

On the *R/V Henry Hudson:*

- A bow mounted Klein 3900 digital side scan sonar towfish was used from 24 August 2013 (JD 236) to 20 October 2013 (JD 293) when the system failed and was replaced with a Klein 3000 digital side scan sonar towfish.
- Klein Sonar Workstation with Windows XP (Service Pack 2) for data collection and logging of side scan sonar data with Klein **SonarPro** software.
- Klein Transceiver Processing Unit.
- Uninterrupted power supplies (UPS) for protection of the entire system.

The Klein 3000 is a conventional dual frequency side scan sonar system. 16-Bit digital side scan sonar data were collected at 100 kHz and 500 kHz concurrently. All side scan data delivered are 16-Bit digital data.

The Klein 3900 is a high resolution switch selectable dual frequency side scan sonar system. 16-Bit digital side scan sonar data were initially collected at 900 kHz from 24 August 2014 (JD 236) to 26 August (JD 238) when it was determined that the quality of the 900 kHz data was unacceptable. From 27 August (JD 239) to 20 October (JD 293) data were collected at 500 kHz. All 900kHz data collected from JD 236 through JD 238 were not used in the final delivered data products, and the corresponding survey lines from this data were all re-run with either the Klein 3900 500kHz setting or with the Klein 3000 side scan sonar system. All side scan data delivered are 16-Bit digital data.

The side scan sonar ping rate is automatically set by the transceiver processing unit based on the range scale setting selected by the user. At a range scale of 50 meters, the ping rate is 15 hertz (Hz) at a range scale of 25 meters, the ping rate is 30 Hz, and at a range scale of 30 meters the ping rate is 25 Hz. Based on these ping rates, maximum survey speeds were established for each range scale setting to ensure that there were a minimum of three pings per meter in the along-track direction, in accordance with Section 6.1.2.2 of the HSSD. The maximum allowable survey speed was 9.7 knots at the 50-meter range therefore the survey speeds were typically less than 8.5 knots.

During survey operations, 16-Bit digital data from the transceiver processing unit were acquired, displayed, and logged by the Klein workstation through the use of Klein's **SonarPro** software. Raw digital side scan data were collected in eXtended Triton Format (XTF) and maintained at full resolution, with no conversion or down sampling techniques applied. Side scan data file names were changed automatically after 80 minutes or manually at the completion of a survey line.

On the *M/V Atlantic Surveyor* these files were archived to the on-board NAS for initial processing and quality control review at the completion of each survey line. At the beginning of each survey day the raw XTF side scan data files from the previous day were backed up on digital magnetic tapes and an external hard drive. All processed side scan data on the NAS were backed up to an external hard drive and magnetic tape approximately every one to two days. The external hard drive and the digital magnetic tape back-ups were shipped to the DPC in Newport, RI, during port calls.

On the *R/V Oyster Bay* and *R/V Henry Hudson* these files were archived to an external hard drive which was used to transfer data to the field office at the end of each survey day for processing. The field office conducted the initial processing and quality control review the following day. At the end of each survey day the raw XTF side scan data files were backed up on digital magnetic tapes. All processed side scan data on the field office processing system was backed up to an external hard drive and magnetic tape approximately every one to two days. The external hard drive and the digital magnetic tape back-ups were shipped to the DPC in Newport, RI, approximately every week.

The Leidos naming convention of side scan XTF data files has been established through the structure of Klein's **SonarPro** software to provide specific identification of the survey vessel ("as" for the *M/V Atlantic Surveyor*, "ob" for the *R/V Oyster Bay*, and "hh" for the *R/V Henry Hudson*), Julian Day that the data file was collected, calendar date, and time that the file was created. For example in side scan file "as320_131116162600.xtf":

- "as" refers to survey vessel *M/V Atlantic Surveyor*.
- 320 refers to Julian Day 320.
- 131116 refers to the year, month and day (YYMMDD), 16 November 2013.
- 1626 refers to the time (HHMM) the file was created.
- 00 refers to a sequential number for files created within the same minute.

As done with bathymetry data, Leidos continuously logged side scan data throughout survey operations and did not stop and re-start logging at the completion and/or beginning of survey lines. Therefore data were typically collected and logged during all turns and transits between survey lines.

Leidos utilized a time window file to distinguish between times of online and offline side scan data. Online side scan data refers to the data logged within a side scan XTF file that were used in the generation of the 1_100% or 2_100% coverage mosaics. Offline side scan data refers to the data logged within a side scan XTF file which were not used for generating either coverage mosaic.

The structure of the time window file was such that each row within the file contained a start and end time for online data. Therefore, offline times of side scan data were excluded from the time window file. The times were represented in each row using date and time stamps for the online times. Also, at the end of each row the associated survey line name was appended to help with processing procedures.

In order to correlate individual side scan files to their associated survey lines, Leidos manually changed side scan file names after the completion of each survey line. Information regarding each survey line name, side scan file used, and the start and end times of online data for each survey line were logged and contained in the "Watchstander Logs" and "Side scan Review Log". These logs are delivered in Separates I of each sheet's Descriptive Report.

For side scan data collected onboard the *M/V Atlantic Surveyor*, the side scan towfish positioning was provided by **ISS-2000** through a **Catenary** program that used cable payout and towfish depth to compute towfish positions. The position of the tow point (or block) was continually computed based on the vessel heading and the known offsets from the acoustic center of the multibeam system to the tow point (See Appendix I). The towfish position was then calculated from the tow point position using the measured cable out (received by **ISS-2000** from the cable payout meter), the towfish pressure depth (sent via a serial interface from the Klein 3000 computer to **ISS-2000**), and the Course Made Good (CMG) of the vessel. The calculated towfish position was sent to the Klein 3000 data collection computer via the **TowfishNav** program module of **ISS-2000**, at least once per second in the form of a GGA (NMEA-183, National Marine Electronics Association, Global Positioning System Fix Data String) message where it was merged with the sonar data file. Cable adjustments were made using a remote winch controller inside the real-time survey acquisition ISO container in order to maintain acceptable towfish altitudes and sonar record quality. Changes to the amount of cable out were automatically saved to the **ISS-2000** message and payout files.

The towed side scan fish altitude was maintained between 8% and 20% of the range scale (2-5 meters at 25-meter range and 4-10 meters at 50-meter range), in accordance with Section 6.1.2.3 of the HSSD, when conditions permitted. For personnel, vessel, and equipment safety, data were occasionally collected at towfish altitudes outside of 8% to 20% of the range over shoal areas and in the vicinity of charted obstructions or wrecks. In some regions of the survey area, the presence of a significant density layer also required that the altitude of the towfish be maintained outside of 8% to 20% of the range to reduce the effect of refraction that could mask small targets in the outer sonar swath range. Periodic confidence checks on linear features (e.g. trawl scars) or geological features (e.g. sand waves or sediment boundaries) were made during data collection to verify the quality of the sonar data across the full sonar record. These periodic confidence checks were made at least once per survey line when possible to do so; however they were always made at least once each survey day in accordance with Section 6.1.3.1 of the HSSD. When the towfish altitude was outside 8% to 20% of the range, the frequency of confidence checks was increased in order to ensure the quality of the sonar data across the full sonar range.

For these surveys, a K-wing depressor was attached directly to the towed side scan and served to keep it below the vessel wake, even in shallow, near shore waters at slower survey speeds. The use of the K-wing reduced the amount of cable out, which in turn reduced the positioning error of the towfish and allowed for less inhibited vessel maneuverability in shallow water.

For side scan data collected onboard the *R/V Oyster Bay* and the *R/V Henry Hudson*, the side scan towfish positioning was provided by **ISS-2000** through a **Catenary** program that used cable payout and towfish depth to compute towfish positions. The position of the tow point (bow mount) was continually computed based on the vessel heading and the known offsets from the acoustic center of the multibeam system to the tow point (See Appendix I). The towfish position was then calculated from the tow point (bow mount) position using a manually set cable out value of 0.0 meters in **ISS-2000**, the towfish pressure depth (sent via a serial interface from the Klein 3000 or Klein 3900 computer to **ISS-2000**), and the Course Made Good (CMG) of the vessel. The calculated towfish position was sent to the Klein 3000 and Klein 3900 data collection computers via the **TowfishNav** program module of **ISS-2000**, at least once per second in the form of a GGA (NMEA-183, National Marine Electronics Association, Global Positioning System Fix Data String) message where it was merged with the sonar data file.

A small timing offset was introduced to the *R/V Henry Hudson* side scan data on Julian Days 240, 243, 244, and 250 based on a time synchronization problem between the side scan acquisition computer and the Kline 3900 Transceiver Processing Unit (TPU) which occurred during boot-up of the TPU. All *R/V Henry Hudson* side scan data were analyzed and all data which showed a position offset as a result of the time synchronization were corrected in post processing though the **SABER Navup** routine which applied a corrected time and position to each each ping. Real-time watch stander procedures were implemented to check correct time synchronization between the side scan acquisition computer and the Kline 3900 TPU. In addition updates to the **ISS-2000 TowfishNav** program settings were made to ensure correct time synchronization between the systems. With these changes implemented no further time synchronization offsets for the *R/V Henry Hudson* side scan data occurred.

A.8 SOUND SPEED PROFILES

A Brooke Ocean Technology Moving Vessel Profiler (MVP) with an Applied Microsystems Smart SV&P Sensor or a Seabird Electronics SBE-19 CTD was used to collect sound speed profile (SSP) data. SSP data were obtained at intervals frequent enough to minimize sound speed errors in the multibeam or singlebeam data. The frequency of SSP casts was based on the following:

- When the difference between the observed surface sound speed measured by a sound speed sensor located at the transducer head or a towed SV&P sensor and the observed sound speed at the transducer depth in the currently applied sound speed profile exceeded 2-meters/second.
- Time elapsed since the last applied SSP cast.
- When a consistent smile or frown was observed in the multibeam ping profile.

Periodically during a survey day, multiple casts were taken along a survey line to identify the rate and location of sound speed changes. Based on the observed trend of sound speed changes along the line where this was done, the SSP cast frequency and locations were modified accordingly for subsequent lines.

Section 5.2.3.3 of the HSSD states:
"… If the surface sound speed sensor value differs by 2 m/s or more from the commensurate cast data, another sound speed cast shall be acquired. Any deviations from this requirement will be documented in the descriptive report."

In order to meet this specification Leidos utilized the **Environmental Manager** module in **ISS-2000** which displayed a real-time time series plot of the sound speed measured at the transducer depth from the currently applied SSP cast and the observed sound speed from the RESON SV 70 located at the transducer head, or towed SV&P sensor, as well as the calculated difference between these sound speed values. A visual warning was issued to the operator when the difference exceeded 2 meters/second. During the surveys it was not always possible to maintain a difference less than 2 meters/second since the MVP sound speed sensor was towed behind the vessel where the upper 3-meters of the water column were mixed by the vessel's props. This was most apparent on warm sunny days with little or no wind when the solar radiation heated the surface water causing a large change in sound speed in near the surface.

In all cases attempts were made to take and apply numerous sound speed profiles. No significant sound speed artifacts (smiles or frowns) in the multibeam were observed during these times.

In accordance with Section 5.2.3.3 of the HSSD, confidence checks of the SSP data were periodically conducted, approximately once per week, by comparing two consecutive casts taken with different SV&P sensors, with a SV&P sensor and a Seabird SBE-19 CTD, or between two different Seabird SBE-19 CTDs. The SSP casts taken during confidence checks were applied to the multibeam file being collected in **ISS-2000** at that time. The application of the profiles allowed **ISS-2000** to maintain a record of each cast. When conducting the SSP comparison casts within the surrounding areas of the survey sheet, one of the comparison cast profiles was commonly applied to the start of the survey line.

Serial numbers and calibration dates are listed below for the Applied Microsystems Smart SV&P Sensors and Seabird CTD sensors used on this survey. Copies of the calibration records are in Appendix IV. Sound speed data are included with the survey data delivered for each sheet. An SSP Application Log, Confidence Check SSP Comparison Cast Log, and sensor calibration records received subsequent to the delivery of this DAPR will be included with the survey data in Separates Section II of the DR for each applicable sheet.

- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 4523, calibration date: 26 January 2013.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 4880, calibration date: 27 January 2013.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5332, calibration date: 26 January 2013.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5454, calibration date: 27 January 2013.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5455, calibration date: 27 January 2013.
- Seabird Electronics, Inc., CTD, Serial Number 193607-565, calibration date: 21 February 2013.
- Seabird Electronics, Inc., CTD, Serial Number 2710, calibration date: 21 February 2013.

The calibration report for the RESON SVP 70 surface sound velocity sensor is included in Appendix IV and with the survey data in Separates Section II of the DR for each sheet if received subsequent to the delivery of this DAPR.

- RESON SVP70, Serial Number 0213030; calibration date: 16 May 2013.
- RESON SVP70, Serial Number 0213031; calibration date: 15 May 2013.

A.9 BOTTOM CHARACTERISTICS

Bottom characteristics were obtained using a WILDCO Petite Ponar Grab (model number 7128-G40) bottom sampler. The locations for acquiring bottom characteristics were provided in the Project Reference File (PRF) by NOAA. From the PRF, Leidos modified the position of bottom sample one, as the location within the PRF did not fall within the survey bounds; Leidos did not modify any other locations from the recommended locations provided by NOAA. At each location a seabed sample was obtained, characterized, and photographed. All photographs were taken with a label showing the survey registration number and sample identification number, as well as a ruler to quantify sample size within the photograph.

Samples were obtained by manually lowering the bottom sampler, with block and line. Each seabed sample was classified using characteristics to quantify color, texture and particle size. The nature of the seabed was characterized as "Unknown" if a bottom sample was not obtained after several attempts.

The position of each seabed sample was marked in the Leidos **ISS-2000** software and logged as an event in the message file. As the event was logged, it was tagged as a bottom sample event with the unique identification number of the sample obtained. These event records in the message file included position, JD, time, and user inputs for depth, the general nature of the type of seabed sample obtained, and any qualifying characteristics to quantify color, texture and grain size.

The bottom sample event records saved in the message files from **ISS-2000** were used to populate Bottom Sample and Watchstander Logs. The Bottom Sample Logs provided all the inputs listed above. The real-time Watchstander Logs provided a record of the time, sample number, sample depth, and sample descriptors for each individual sample obtained.

Bottom characteristics are included within the S-57 Feature File for each sheet, categorized as Seabed Areas (SBDARE) and attributed based on the requirements of the International Hydrographic Organization (IHO) Special Publication No. 57, "*IHO Transfer Standard for Digital Hydrographic Data*", Edition 3.1, (see Section B.2.6 for details of the S-57 feature file). In addition to being maintained within the feature file for each sheet, a table summarizing the bottom characteristics is presented in Appendix II of each sheet's Descriptive Report. Digital photographic images of each bottom sample are also included in the S-57 Feature file for each sheet.

A.10 DATA ACQUISITION AND PROCESSING SOFTWARE

Data acquisition was carried out using the Leidos **ISS-2000** software for Windows XP operating systems to control acquisition navigation, data time tagging, and data logging. **ISS-2000** Version 4.5.0.6.0 was installed onboard the *M/V Atlantic Surveyor*. **ISS-2000** Version 4.5.0.6.2 was released after the SAT and start of survey on TO-08 for the *M/V Atlantic Surveyor*, and only provided updates specific to singlebeam operations not needed on the *M/V Atlantic Surveyor*. **ISS-2000** Version 4.5.0.6.2 was installed onboard the *R/V Oyster Bay* and the *R/V Henry Hudson*.

Survey planning, data processing, and analysis were carried out using the Leidos **Survey Planning** and **SABER** Version 5.1.4.6.4 software for Linux operating systems. Periodic upgrades to this software were installed in the Newport, RI Data Processing Center, on the survey vessel *M/V Atlantic Surveyor*, and in the Middletown, NJ Field Office. The version and installation dates for each upgrade are listed in Table A-2.

Table A-2. SABER Versions and Installations Dates

Newport DPC SABER and Survey Planning Version	Date Version Installed In Newport, RI	Date Version Installed In Field	Software Use
5.1.4.6.4	11 April 2014		General
5.1.3.6.4	17 July 2013	18 August 2013	General
5.1.3.6.5	07 October 2013		General
5.1.3.6.8	25 October 2013		General
5.1.3.6.10	02 December 2013		General
5.1.3.6.15	02 January 2014	07 January 2014	General
5.1.4.6.1	24 March 2014		General
5.1.4.6.2	25 March 2014		General
5.1.4.6.3	07 April 2014		General
4.3.0.17.1	11 April 2014		BAG 1.10 Generation Only

SonarPro Version 11.3, running on a Windows XP platform was used for side scan data acquisition onboard the *M/V Atlantic Surveyor* and the *R/V Oyster Bay*. **SonarPro** Version 12.1, running on a Windows XP platform was used for side scan data acquisition onboard the *R/V Henry Hudson* from 24 August 2013 (JD 236) to 20 October 2013 (JD 239) while the Klein 3900 was in use. **SonarPro** Version 11.3 was then used with the Klein 3000 system from 21 October 2013 (JD 240) through the completion of the *R/V Henry Hudson* survey operations on 25 October 2013 (JD 244).

The NOAA Extended Attribute Files V5_2 was used as the Feature Object Catalog for all sheets on this project.

A.11 SHORELINE VERIFICATION

Shoreline verification was not required for this survey.

B. QUALITY CONTROL

A systematic approach to tracking data has been developed to maintain data quality and integrity. Several logs and checklists have been developed to track the flow of data from acquisition through final processing. These forms are presented in the Separates Section I included with the data for each survey.

During data collection, survey watch standers continuously monitored the systems, checking for errors and alarms. Thresholds set in the **ISS-2000** system parameters alerted the watch stander by displaying alarm messages when error thresholds or tolerances were exceeded. Alarm conditions that may have compromised survey data quality were corrected and noted in both the navigation log and the message files. Warning messages such as the temporary loss of differential GPS, excessive cross track error, or vessel speed approaching the maximum allowable survey speed were addressed by the watch stander and automatically recorded into a message file. Approximately every 2-3 hours the acquisition watch standers completed checklists to verify critical system settings and ensure valid data collection.

Following data collection, initial data processing began either on-board the survey vessel or in the field office. This included the first level of quality assurance:

- Initial swath editing of multibeam and singlebeam data flagging invalid pings and beams.
- Application of delayed heave (Applanix *TrueHeave*™).
- Calculation of Total Propagated Uncertainty (TPU).
- Generation of a preliminary Pure File Magic (PFM) CUBE surface.
- Second review and editing of multibeam data PFM CUBE surface.
- Open beam angles where appropriate to identify significant features outside the cut-off angle.
- Identify significant features for investigation with additional multibeam coverage.
- Turning unacceptable data offline.
- Turning additional data online.
- Identification and flagging of significant features.
- Track plots.
- Preliminary minimum sounding grids.
- Crossline checks.
- Running side scan data through Automatic Contact Detection (ACD).
- Application of Trained Neural Network to flag false alarms in side scan detections.
- Hydrographer review of side scan data.
- Generation of side scan contact files.
- Generation of preliminary side scan coverage mosaics.
- Identification of holidays in the side scan coverage.

On a daily basis, the multibeam and singlebeam data were binned to minimum depth layers, populating each bin with the shoalest sounding in that bin while maintaining its true position and depth. The following binned grids were created and used for initial crossline analysis, tide zone boundary comparisons, and day-to-day data comparisons:

- Main scheme, item, and holiday fill survey lines.
- Crosslines using only near-nadir data (±5° from nadir).

These daily comparisons were used to monitor adequacy and completeness of data and sounding correctors.

Approximately once a week a complete backup of all raw and processed multibeam data and side scan data was sent to the Leidos DPC in Newport, RI. Complete analysis of the data at the Newport facility included the following steps:

- Generation of multibeam and side scan track line plots.
- Verification of side scan contact files.
- Application of prorated draft to multibeam data.
- Application of verified water level correctors to multibeam data.
- Computation of Total Propagated Uncertainty (TPU) for each depth value in the multibeam data.
- Generation of a two-meter CUBE PFM surface for analysis of coverage, areas with high TPU, and features.
- Crossline analysis of multibeam data.
- Comparison with prior surveys.
- Generation of final CUBE PFM surface(s).
- Generation of S-57 feature file.
- Comparison with existing charts.
- Quality control reviews of side scan data and contacts.
- Final coverage mosaics of side scan sonar data.
- Correlation of side scan contacts with multibeam features.
- Generation of final Bathymetric Attributed Grid(s) (BAG) and metadata products.
- Final quality control of all delivered data products.

A flow diagram of Leidos data processing routines from the acquisition of raw soundings to the final grids and deliverable data can be found in Appendix II.

B.1 SURVEY SYSTEM UNCERTAINTY MODEL

The Total Propagated Uncertainty (TPU) model used by **SABER** estimates each of the components that contribute to the overall uncertainty that is inherent in each sounding. The model then calculates cumulative system uncertainty (Total Propagated Uncertainty). The data needed to drive the error model were captured as parameters taken from the **SABER** Error Parameter File (EPF), which is an ASCII text file typically created during survey system installation and integration. The parameters were also obtained from values recorded in the multibeam GSF file(s) during data collection and processing. While the input units vary, all uncertainty values that contributed to the cumulative TPU estimate were eventually converted to meters by the **SABER Calculate Errors in GSF** program. The TPU estimates were recorded as the Horizontal Uncertainty and Vertical Uncertainty at the 95% confidence level for each beam in the GSF file. Individual soundings that had vertical and horizontal uncertainty values above IHO Order 1a were flagged as invalid during uncertainty attribution.

Table B-1 through Table B-7 show the values entered in to separate **SABER** EPF used with this project. All parameter uncertainties in this file were entered at the one sigma level of confidence, but the outputs from **SABER's Calculate Errors in GSF** program are at the two sigma or 95% confidence level. Sign conventions are: X = positive forward, Y = positive starboard, Z = positive down.

Table B-1. *M/V Atlantic Surveyor* Error Parameter File (EPF) for the RESON 7125

Parameter	Value	Units
VRU Offset – X	0.347	Meters
VRU Offset – Y	0.291	Meters
VRU Offset – Z	-1.787	Meters
VRU Offset Error – X (uncertainty)	0.015	Meters
VRU Offset Error – Y (uncertainty)	0.011	Meters
VRU Offset Error – Z (uncertainty)	0.013	Meters
VRU Latency	0.00	Millisecond
VRU Latency Error (uncertainty)	1.00	Milliseconds
Heading Measurement Error (uncertainty)	0.02	Degrees
Roll Measurement Error (uncertainty)	0.02	Degrees
Pitch Measurement Error (uncertainty)	0.02	Degrees
Heave Fixed Error (uncertainty)	0.05	Meters
Heave Error (% error of height) (uncertainty)	5.00	Percent
Antenna Offset – X	4.609	Meters
Antenna Offset – Y	-0.374	Meters
Antenna Offset – Z	-8.168	Meters
Antenna Offset Error – X (uncertainty)	0.015	Meters
Antenna Offset Error – Y (uncertainty)	0.014	Meters
Antenna Offset Error – Z (uncertainty)	0.011	Meters
Estimated Error in Vessel Speed (uncertainty)	0.0300	Knots
Percent of Speed Contributing to Speed Error	0.00	Percent
GPS Latency	0.00	Milliseconds
GPS Latency Error (uncertainty)	1.00	Milliseconds
Horizontal Navigation Error (uncertainty)	0.75*	Meters
Vertical Navigation Error (uncertainty)	0.20*	Meters
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters
Settlement & Squat Error (uncertainty)	0.0252	Meters
Predicted Tide Measurement Error (uncertainty)	0.17	Meters
Observed Tide Measurement Error (uncertainty)	0.07	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.10	Meters
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SEP Uncertainty	0.15	Meters
SVP Measurement Error (uncertainty)	1.00	Meters/second

*NOTE: These values would only be used if not included in the GSF file

Table B-2. *R/V Oyster Bay* Error Parameter File (EPF) for the Odom CVM

Parameter	Value	Units
VRU Offset – X	4.029	Meters
VRU Offset – Y	0.781	Meters
VRU Offset – Z	0.949	Meters

Parameter	Value	Units
VRU Offset Error – X (uncertainty)	0.013	Meters
VRU Offset Error – Y (uncertainty)	0.0116	Meters
VRU Offset Error – Z (uncertainty)	0.0136	Meters
VRU Latency	0.00	Millisecond
VRU Latency Error (uncertainty)	1.00	Milliseconds
Heading Measurement Error (uncertainty)	0.02	Degrees
Roll Measurement Error (uncertainty)	0.02	Degrees
Pitch Measurement Error (uncertainty)	0.02	Degrees
Heave Fixed Error (uncertainty)	0.05	Meters
Heave Error (% error of height) (uncertainty)	5.00	Percent
Antenna Offset – X	1.282	Meters
Antenna Offset – Y	0.762	Meters
Antenna Offset – Z	-2.948	Meters
Antenna Offset Error – X (uncertainty)	0.0176	Meters
Antenna Offset Error – Y (uncertainty)	0.0122	Meters
Antenna Offset Error – Z (uncertainty)	0.0165	Meters
Estimated Error in Vessel Speed (uncertainty)	0.0300	Knots
Percent of Speed Contributing to Speed Error	0.00	Percent
GPS Latency	0.00	Milliseconds
GPS Latency Error (uncertainty)	1.00	Milliseconds
Horizontal Navigation Error (uncertainty)	0.75*	Meters
Vertical Navigation Error (uncertainty)	0.00*	Meters
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.034	Meters
Settlement & Squat Error (uncertainty)	0.01	Meters
Predicted Tide Measurement Error (uncertainty)	0.17	Meters
Observed Tide Measurement Error (uncertainty)	0.07	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.10	Meters
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SEP Uncertainty	0.15	Meters
SVP Measurement Error (uncertainty)	1.00	Meters/second

*NOTE: These values would only be used if not included in the GSF file

Table B-3. *R/V Oyster Bay* Error Parameter File (EPF) for the RESON 8101

Parameter	Value	Units
VRU Offset – X	4.141	Meters
VRU Offset – Y	0.757	Meters
VRU Offset – Z	-0.781	Meters
VRU Offset Error – X (uncertainty)	0.0145	Meters
VRU Offset Error – Y (uncertainty)	0.0142	Meters
VRU Offset Error – Z (uncertainty)	0.0143	Meters
VRU Latency	0.00	Millisecond
VRU Latency Error (uncertainty)	1.00	Milliseconds
Heading Measurement Error (uncertainty)	0.02	Degrees
Roll Measurement Error (uncertainty)	0.02	Degrees
Pitch Measurement Error (uncertainty)	0.02	Degrees
Heave Fixed Error (uncertainty)	0.05	Meters
Heave Error (% error of height) (uncertainty)	5.00	Percent
Antenna Offset – X	1.394	Meters
Antenna Offset – Y	0.738	Meters

Parameter	Value	Units
Antenna Offset – Z	-2.780	Meters
Antenna Offset Error – X (uncertainty)	0.0145	Meters
Antenna Offset Error – Y (uncertainty)	0.0142	Meters
Antenna Offset Error – Z (uncertainty)	0.0143	Meters
Estimated Error in Vessel Speed (uncertainty)	0.0300	Knots
Percent of Speed Contributing to Speed Error	0.00	Percent
GPS Latency	0.00	Milliseconds
GPS Latency Error (uncertainty)	1.00	Milliseconds
Horizontal Navigation Error (uncertainty)	0.75*	Meters
Vertical Navigation Error (uncertainty)	0.00*	Meters
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters
Settlement & Squat Error (uncertainty)	0.0335	Meters
Predicted Tide Measurement Error (uncertainty)	0.17	Meters
Observed Tide Measurement Error (uncertainty)	0.07	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.10	Meters
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SEP Uncertainty	0.15	Meters
SVP Measurement Error (uncertainty)	1.00	Meters/second

*NOTE: These values would only be used if not included in the GSF file

Table B-4. *R/V Henry Hudson* Error Parameter File (EPF) for the RESON 8101

Parameter	Value	Units
VRU Offset – X	1.276	Meters
VRU Offset – Y	2.499	Meters
VRU Offset – Z	-2.010	Meters
VRU Offset Error – X (uncertainty)	0.0204	Meters
VRU Offset Error – Y (uncertainty)	0.00115	Meters
VRU Offset Error – Z (uncertainty)	0.0278	Meters
VRU Latency	0.00	Millisecond
VRU Latency Error (uncertainty)	1.00	Milliseconds
Heading Measurement Error (uncertainty)	0.02	Degrees
Roll Measurement Error (uncertainty)	0.02	Degrees
Pitch Measurement Error (uncertainty)	0.02	Degrees
Heave Fixed Error (uncertainty)	0.05	Meters
Heave Error (% error of height) (uncertainty)	5.00	Percent
Antenna Offset – X	0.390	Meters
Antenna Offset – Y	1.483	Meters
Antenna Offset – Z	-6.466	Meters
Antenna Offset Error – X (uncertainty)	0.0204	Meters
Antenna Offset Error – Y (uncertainty)	0.0083	Meters
Antenna Offset Error – Z (uncertainty)	0.0278	Meters
Estimated Error in Vessel Speed (uncertainty)	0.0300	Knots
Percent of Speed Contributing to Speed Error	0.00	Percent
GPS Latency	0.00	Milliseconds
GPS Latency Error (uncertainty)	1.00	Milliseconds
Horizontal Navigation Error (uncertainty)	0.75*	Meters
Vertical Navigation Error (uncertainty)	0.00*	Meters
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters

Parameter	Value	Units
Settlement & Squat Error (uncertainty)	0.0357	Meters
Predicted Tide Measurement Error (uncertainty)	0.17	Meters
Observed Tide Measurement Error (uncertainty)	0.07	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.10	Meters
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SEP Uncertainty	0.15	Meters
SVP Measurement Error (uncertainty)	1.00	Meters/second

*NOTE: These values would only be used if not included in the GSF file

Table B-5. RESON 7125 SV Sonar Parameters

Parameter	Value	Units
Transducer Offset – X	0.00*	Meters
Transducer Offset – Y	0.00*	Meters
Transducer Offset – Z	0.00*	Meters
Transducer Offset Error – X (uncertainty)	0.015	Meters
Transducer Offset Error – Y (uncertainty)	0.011	Meters
Transducer Offset Error – Z (uncertainty)	0.013	Meters
Roll Offset Error (uncertainty)	0.05	Degrees
Pitch Offset Error (uncertainty)	0.05	Degrees
Heading Offset Error (uncertainty)	0.05	Degrees
Model Tuning Factor	6.00	N/A
Amplitude Phase Transition	1.0	Samples
Latency	0.00	Milliseconds
Latency Error (uncertainty)	1.00	Milliseconds
Installation Angle	0.0	Degrees

*NOTE: These values would only be used if not included in the GSF file

Table B-6. RESON 8101 ER Sonar Parameters

Parameter	Value	Units
Transducer Offset – X	0.00*	Meters
Transducer Offset – Y	0.00*	Meters
Transducer Offset – Z	0.00*	Meters
Transducer Offset Error – X (uncertainty)	0.02	Meters
Transducer Offset Error – Y (uncertainty)	0.02	Meters
Transducer Offset Error – Z (uncertainty)	0.02	Meters
Roll Offset Error (uncertainty)	0.02	Degrees
Pitch Offset Error (uncertainty)	0.02	Degrees
Heading Offset Error (uncertainty)	0.02	Degrees
Model Tuning Factor	6.00	N/A
Amplitude Phase Transition	1.0	Samples
Latency	0.00	Milliseconds
Latency Error (uncertainty)	1.00	Milliseconds

*NOTE: These values would only be used if not included in the GSF file

Table B-7. ODOM CVM Sonar Parameters

Parameter	Value	Units
Transducer Offset – X	0.00*	Meters
Transducer Offset – Y	0.00*	Meters
Transducer Offset – Z	0.00*	Meters
Transducer Offset Error – X (uncertainty)	0.0130	Meters
Transducer Offset Error – Y (uncertainty)	0.0116	Meters
Transducer Offset Error – Z (uncertainty)	0.0136	Meters
Roll Offset Error (uncertainty)	0.01	Degrees
Pitch Offset Error (uncertainty)	0.01	Degrees
Heading Offset Error (uncertainty)	0.01	Degrees
Model Tuning Factor	6.00	N/A
Amplitude Phase Transition	99	Samples
Latency	0.00	Milliseconds
Latency Error (uncertainty)	0	Milliseconds
Installation Angle	0.0	Degrees

*NOTE: These values would only be used if not included in the GSF file

B.2 MULTIBEAM AND SINGLEBEAM DATA PROCESSING

At the end of each survey line file names were changed in **ISS-2000**, which automatically closed all data files and opened new files for data logging. The closed files were then archived to the on-board NAS or external hard drive and data processing commenced (immediately onboard the *M/V Atlantic Surveyor,* and upon delivery of the external hard drive from the survey vessel to the Field Office) with the review of multibeam data files to flag erroneous data such as noise, flyers or fish, and to designate features. Please note that the GSF files collected and delivered for sheets H12586 and H12587 are GSF version 03.04. CARIS HIPS and SIPS version 7.1 Service Pack 2 Hotfix 6 and later versions are compatible with GSF version 03.04. The bathymetry data were reviewed and edited, on-board the vessel or in the Field Office, using the Leidos **Multi-View Editor** (**MVE**) program. This tool is a geo-referenced editor, which can project each beam in its true geographic position and depth in both plan and profile views. Positions and depths of features were determined directly from the bathymetry data in the Leidos **MVE** swath editor by flagging the least depth on the object. A bathymetry feature file (CNT) was created using the **SABER Feature/Designated File from GSF** routine. The CNT file contains the position, depth, type of feature, and attributes extracted from the flagged features in the GSF multibeam data.

Once the bathymetry data were reviewed and edited, delayed heave was applied to the GSF files. The process to apply delayed heave uses the Applanix *TrueHeave*™ (.thv) files (for further detail refer to Section C.3). Leidos refers to true heave as delayed heave. Next, preliminary TPU values were computed for each beam in the GSF files before they were loaded into a two-meter PFM CUBE surface. Further review and edits to the data were performed from the CUBE PFM grid. Periodically both the raw and processed data were backed up onto digital tapes and external hard drives. These tapes and hard drives were shipped to the DPC in Newport, RI at each port call.

Once the data were in Newport and extracted to the NAS unit for the DPC, verified water levels were applied to the data, as well as prorated static draft if applicable. The final TPU for each beam was then calculated and applied to the bathymetry data.

For each survey sheet, all bathymetry data were processed into a two-meter node PFM CUBE surface for analysis using **SABER** and **MVE**. The two-meter node PFM CUBE surface was generated to demonstrate coverage for the entire sheet. All individual soundings used in development of the final CUBE depth surface had modeled vertical and horizontal uncertainty values at or below the allowable maximum uncertainty as specified in Section 5.1.3 of the HSSD.

Two separate uncertainty surfaces are calculated by the **SABER** software, Hypothesis Standard Deviation and Hypothesis Average Total Propagated Uncertainty (Average TPU). The Hypothesis Standard Deviation is a measure of the general agreement between all of the soundings that contributed to the best hypothesis for each node. The Hypothesis Average TPU is the average of the vertical uncertainty component for each sounding that contributed to the best hypothesis for the node. A third uncertainty surface is generated from the larger of these two uncertainties at each node and is referred to as the Hypothesis Final Uncertainty.

After creation of the initial two-meter PFM CUBE surfaces, the **SABER Check PFM Uncertainty** function was used to highlight all of the cases where computed final node uncertainties exceeded IHO Order 1a. These nodes were investigated individually and typically highlighted areas where additional cleaning was necessary. Nodes found in the final grid that still exceed uncertainty were addressed in the Descriptive Report for each sheet. When all GSF files and the PFM CUBE surface were determined to be satisfactory, the PFM CUBE grid was converted to BAG files for final delivery.

B.2.1 Multibeam and Singlebeam Coverage Analysis

Bathymetric coverage analysis was conducted during data processing and on the final CUBE surface to identify areas where data coverage holidays exceeded the allowable three contiguous nodes in accordance with Section 5.2.2.3 of the HSSD. As previously stated in Section A.6, these survey operations were conducted at set line spacing optimized to achieve 200% side scan sonar coverage; 100% multibeam coverage was not required.

The **SABER Gapchecker** utility was run on the CUBE surface to identify data holidays exceeding the allowable three contiguous nodes within the bathymetry data. In addition, the entire surface was visually scanned for holidays. Before closing out field operations, additional survey lines were run to fill any holidays that were detected. Results of the bathymetry coverage analysis are presented in Section B.2.9 of each sheet's Descriptive Report.

All grids for each survey were also examined for the number of soundings contributing to the chosen CUBE hypothesis for each node. This was done by running **SABER's Frequency Distribution** tool on the Hypothesis Number of Soundings layer. This analysis was done to ensure that at least 95% of all nodes contained five or more soundings, ensuring the requirements for set line spacing coverage as specified in Section 5.2.2.3 of the HSSD were met. A complete analysis of the results of the **Frequency Distribution** tool is provided in Section B.2.9 of the DR for each sheet.

B.2.2 Junction Analysis

During data acquisition, comparisons of main scheme (±60 degrees) to crossline near nadir (±5 degrees) data were conducted daily to ensure that no systematic errors were introduced and to identify potential problems with the survey system. Final junction analysis was again conducted after the application of all correctors and completion of final processing to assess the agreement between the main scheme and crossline data that were acquired during the survey. Because the crosslines were acquired at varying time periods throughout the survey period, the crossline analyses provided an indication of potential temporal issues (e.g., tides, speed of sound, draft) that may affect the data. Additionally junction analysis was conducted between survey sheets which share a common boundary, and where the data have been fully processed. For junction analysis, the data were binned at a two-meter grid resolution using the CUBE algorithm. The following binned grids were created and used for junction analysis:

- Main scheme, item, and holiday fill survey lines (full valid swath, ±60° cutoff)
- Crosslines (Class 1 data only, ±5° cutoff)
- All online data collected during survey (full valid swath, ±60° cutoff)

The junction analysis was performed by subtracting a grid from a separate reference grid to create a depth difference grid. For instance, if the crossline grid was subtracted from the main scheme grid (reference layer) then a positive depth difference would indicate that the main scheme data are deeper than the crossline data, and a negative depth difference would indicate that the main scheme data are shoaler than the crossline data. The **SABER Frequency Distribution** tool was used on the resulting depth difference grid for the junction analysis and statistics. The number count and percentage of depth difference values resulting from the frequency distribution tool were calculated and reported four ways; as a total of all difference values populating the cells of the difference grid, as the amount of positive difference values populating the cells of the difference grid, as the amount of negative difference values populating the cells of the difference grid, and as the amount of values populating the cells of the difference grid which resulted in a zero difference. This was used to provide an analysis of the repeatability of the multibeam data system. A frequency distribution could not only be run on the overall resulting difference grid but could be run on any subarea of the difference grid. This was done to isolate areas, such as along tide zone boundaries and areas of high depth difference, to better evaluate and investigate potential accuracy problems.

Results of the junction analyses are presented in Separates II of the DR for each survey.

B.2.3 Crossing Analysis

A beam-to-beam comparison of crossline data to mainscheme data was not performed. Leidos conducted analysis on a difference surface as discuss in Section B.2.2.

B.2.4 The CUBE Surface

Combined Uncertainty and Bathymetry Estimator (CUBE) is an internationally recognized model that provides the ability to convert bathymetry data and their associated uncertainty estimates into a gridded model. CUBE was developed by Brian Calder and others at the Center for Costal Ocean Mapping Joint Hydrographic Center (CCOM-JHC). Leidos is a member of the CCOM Consortium and the CUBE algorithm has been licensed to Leidos for use in **SABER**.

The CUBE algorithm uses the full volume of the collected data and the propagated uncertainty values associated with each sounding to perform a statistical analysis and calculate an estimated “true depth” at a series of nodes. The depth estimates and the associated uncertainty values at each node are grouped into a series of hypotheses or alternate depth estimates. Each node can have several hypotheses, of which the CUBE algorithm determines the hypothesis that best represents the “true depth” at each node using one of several user-selectable disambiguation methods. For all data processing the “Prior” disambiguation method was used in **SABER’s** implementation of CUBE. Once the “best” hypothesis had been selected for each node, the hypotheses were used to populate a bathymetric surface.

Four processing stages within the CUBE algorithm method; the Scatter Stage, the Gather Stage, the Insertion Stage, and the Extraction Stage were used to create the bathymetric CUBE surfaces.

The Scatter Stage determines which nodes might accept a sounding based on spatial criteria and that sounding’s TPU values. This is done by calculating a radius of influence for each sounding, which will always be greater than or equal to the node spacing and less than or equal to the maximum radius. The maximum radius is equal to the 99% confidence limit of the horizontal uncertainty of the sounding. This radius of influence thereby determines the subset of nodes that can be affected by a sounding, by checking the distance of the sounding-to-node-position against the radius. If the distance from the sounding to the node is greater than the radius of influence, the processing of that sounding in the current node will end before the next stage of CUBE begins.

Once the CUBE algorithm defines the nodes that may be affected by a sounding, the Gather Stage then determines which soundings are actually inserted into the node. This is done through the use of a calculated node-to-sounding capture distance for each node in the subset of a sounding. The capture distance is equal to the greater of; 5% of the depth of the current sounding, the node spacing, or 0.50 meters.

For each of the nodes in the subset of a sounding, the sounding is only propagated to a node that falls within both the Scatter Stage radius and the Gather Stage capture distance. Also, the sounding to node propagation distance is additionally limited to a distance less than or equal to the grid resolution divided by the square root of two. This additional propagation distance limitation was included in **SABER’s** implementation of CUBE in order to meet the requirements of Section 5.2.2 of the HSSD. These distance limitations prevent soundings from being propagated far away from their collection points, as well as limiting how far away "bad" (high TPU) data are propagated.

Next, in the Insertion Stage, the soundings are actually added to nodes. **SABER** uses CUBE's "order 0" propagation approach. That is, when a sounding is propagated from its observed location to the node, the sounding depth will remain constant. However, the vertical uncertainty will change. The sounding's vertical uncertainty is increased by a dilution factor calculated from the distance of the sounding to the node and the sounding's horizontal uncertainty. This increase in the sounding's vertical uncertainty is affected by the user-defined distance exponent.

Addition of a sounding to a node starts by insertion of the sounding's depth, vertical uncertainty, and propagated variance into a node-based queue structure. Each node has a queue where soundings are written prior to calculation of a hypothesis. The queue is used to delay the impact of outliers on the hypothesis. Currently, the queue limit within **SABER** is 11 soundings. CUBE will not calculate a depth hypothesis for a node until all available soundings have entered the queue or there are at least 11 soundings and their associated propagated variance values in that node's queue.

As each sounding enters the queue, the queue is sorted by depth. Once 11 or all available soundings are in the queue, CUBE finds the median sounding for that group of soundings and inserts the sounding and its propagated variance into the node. Once the median sounding has been written to the node, another sounding is inserted into the queue and all soundings are resorted by depth. CUBE continues this process using batches of 11 soundings until there are no more soundings to insert into the node's queue. At this point, the algorithm will continue sorting the queue by depth using any soundings that remain, finding the median of the last ten soundings in the queue, then the last nine soundings, etc., until every sounding has been incorporated into a hypothesis. This process keeps possible fliers at the high and low ends of the queue until all other soundings have been processed, which has the net effect of creating a stronger hypothesis earlier in the process.

For each sounding to be inserted into a node, CUBE will determine if the sounding qualifies to be included in an existing hypothesis. If it qualifies for more than one hypothesis, CUBE will choose the hypothesis that will have the smallest change in variance when updated with the new sounding. If the statistical analysis within CUBE determines that the sounding does not fall into an existing hypothesis, then it will create a new hypothesis. Each sounding propagated to a certain node will influence one and only one hypothesis for that node. However, each sounding may affect multiple nodes.

Once all of the soundings have been propagated to nodes and inserted into depth hypotheses, CUBE will populate a bathymetric surface with the "best" hypothesis from each node in the Extraction Stage. If each node has only one depth hypothesis, then that hypothesis will be used for the surface. If there are multiple hypotheses for a node, **SABER's** CUBE implementation extracts the "best" hypothesis from the nodes using one of three user-selected disambiguation methods to determine the best estimate of the true depth.

As previously mentioned, of the three available user-selectable disambiguation methods included in **SABER's** implementation of CUBE, the "Prior" disambiguation method was used for all data processing of this project's surveys. This method, which is the simplest of the three methods, looks for the hypothesis with the greatest number of soundings and selects it as the "best" depth estimate. This method does not take the cumulative uncertainty of each hypothesis into consideration; it is strictly a count of the soundings in each hypothesis. If two hypotheses have the same number of soundings the program will choose the last hypothesis.

The "Prior" disambiguation method calculates the hypothesis strength based on a ratio of the number of samples in the "best" hypothesis and the samples in the next "best" hypothesis. This value is interpreted as the closer to zero, the more certainty of this hypothesis representing the true bottom. As the ratio values approach 5.0, that certainty diminishes rapidly. Any values less than zero are set to zero.

During the Extraction Stage, CUBE will also convert the running estimate of variance values that it has been calculating into a standard deviation and then into the Confidence Interval (CI) specified. The 95% CI was used for this project's surveys.

The Hypothesis Strength in conjunction with the number of hypotheses, the uncertainty of each hypothesis, and the number of soundings in each hypothesis are all helpful in determining the confidence in the final depth estimate for each node.

SABER has incorporated CUBE processing into the PFM layer structure. As an option when building a PFM layer, the user can choose to run the CUBE process which adds a series of additional surfaces to the PFM layer:

- *CUBE Depth*, which contains the depth value from the node's best hypothesis (unless there is an over-ride).
- *Node Shoal Depth,* which contains the shoalest depth of the soundings in the chosen CUBE hypothesis.
- *Node Number of Hypotheses*, which shows the number of hypotheses that were generated for each node.
- *Hypothesis Standard Deviation*, which shows the CUBE algorithm's calculated depth uncertainty for the best hypothesis of a node. This is reported at the CI selected by the user during the PFM build process (95% CI for all surveys). This is simply a measure of how well the soundings that made up a hypothesis compare to each other. It is not a measure of how good the soundings are.
- *Node Hypothesis Strength*, which shows a node-by-node estimate for how strongly supported a hypothesis depth estimate is. This value is calculated as follows: a ratio of the number of samples in the "best" hypothesis and the samples in the next "best" hypothesis is generated. The ratio is subtracted from an arbitrary limit of 5. The hypothesis strength is interpreted as the closer this

value is to zero, the stronger the hypothesis. If the resulting product is less than zero, it will be reported as a zero.

- *Hypothesis Number of Soundings*, which reports the number of soundings that were used to calculate the best hypothesis.
- *Hypothesis Average TPU*, is a second uncertainty value calculated by **SABER**, not the CUBE algorithm. This value is computed by taking the average of the vertical component of the TPU for each sounding that contributed to the best hypothesis for the node. It provides an alternative method for describing the likely depth uncertainty for nodes. The average TPU value does provide a measure of how good the soundings are that made up the hypothesis.
- *Hypothesis Final Uncertainty*, this surface is populated with the greater value of the Hypothesis Standard Deviation and the Hypothesis Average TPU surfaces.

Once built, the different PFM surfaces were displayed, analyzed, and edited using **SABER**. All PFM surfaces were used throughout the data processing stages to aid in analysis, interpretation, and editing of the survey data, as well as for QA/QC tools to ensure specifications of the HSSD were met. When all survey data were finalized, Leidos built a final PFM using the CUBE option. This final PFM, and all associated surfaces, were run though a final QC procedure, and it was then used in Leidos' combined CUBE/BAG approach implemented within **SABER**. Here **SABER** provided the ability to directly export the CUBE Depth surface and associated Final Uncertainty surface from the PFM to a BAG layer. This process was done through the use of the **Convert PFM to BAG** utility in **SABER**. This same process was also used to produce the additional non-standard BAG files requested by NOAA's Atlantic Hydrographic Branch (AHB). The BAG layer and the additional non-standard BAG files are described in the next section (Section B.2.5).

B.2.5 Bathymetric Attributed Grids

A Bathymetric Attributed Grid (BAG) is a bathymetry data file format developed by the Open Navigation Surface Working Group (ONSWG). This group developed the BAG file format in response to the growing need within the hydrographic community for a nonproprietary data exchange format for bathymetric grids and associated uncertainty data.

One of the key requirements for Navigation Surfaces, and hence for BAG layers, is that all depth values have an associated uncertainty estimate and that these values must be co-located in a gridded model, which provides the best estimate of the bottom. To meet this requirement Leidos has implemented a combined CUBE/BAG approach in **SABER** (see Section B.2.4 for a detailed description about the CUBE Surface). In this approach, **SABER** creates BAG layers by converting the CUBE Depth surface and associated Hypothesis Final Uncertainty surface of a PFM grid to a BAG.

This process was done through the use of the **Convert PFM to BAG** utility in **SABER**. This utility allowed user-selected surfaces of a PFM to be converted into one or more BAG layers. For example, the PFM depth surface was converted to the BAG file's depth surface, and the PFM uncertainty surface was converted to the BAG file's uncertainty surface.

As of the date of delivery of this DAPR, the hotfix for CARIS does not support version 1.5.1 BAGs with optional surfaces. Therefore, BAG version 1.1.0 files will be delivered for each sheet. Since the BAG version 1.1.0 files only contain two surfaces, the standard CUBE Depth and Final Uncertainty, BAGs will be delivered along with the additional surfaces delivered as supplemental non-standard BAG files. These additional BAG files were generated through the same process as the standard BAG files. The version 1.1.0 BAG format only allows for a Depth surface and an Uncertainty surface. Therefore, each of the non-standard BAG files were created with the CUBE Depth values populating the Depth surface of the BAG and each of the additional group surfaces listed below populating the Uncertainty surface of the BAG. Non-standard BAG files for this project are only delivered for the two-meter grid resolution.

Please note when reviewing these additional, non-standard version 1.1.0 BAG files the file name designates the layer which populates the Uncertainty layer of the BAG. Please also note that when displayed the two layers of the BAG remain named Depth and Uncertainty. These non-standard BAGs are provided for review purposes only and are not intended to be used as archival products. These additional surfaces are referred to as Elevation Solution Group surfaces and Node Group surfaces.

Note that by definition, BAG files contain elevations not depths however; many software packages display a BAG elevation surface as a depth (positive values indicating water depth).

The Elevation Solution Group is made up of the following three surfaces:

- *shoal elevation* - the elevation value of the least-depth measurement selected from the sub-set of measurements that contributed to the elevation solution.
- *number of soundings* - the number of elevation measurements selected from the sub-set of measurements that contributed to the elevation solution.
- *stddev* - the standard deviation computed from all elevation values which contributed to any hypothesis within the node. Note that the *stddev* value is computed from all measurements contributing to the node, whereas *shoal elevation* and *number of soundings* relate only to the chosen elevation solution.

The Node Group is made up of the following two surfaces:

- *hypothesis strength* - the CUBE computed strength of the chosen hypothesis
- *number of hypotheses* - the CUBE computed number of hypotheses

The **SABER Convert PFM to BAG** utility populates each layer of the BAG from the corresponding layer of the CUBE PFM and maintains the PFM grid resolution. The final delivered BAG files for this project include both the Elevation (Depth) Solution Group surfaces and the Node Group surfaces.

A supplemental standard two-meter resolution BAG and the five non-standard BAGs were also delivered, populated with only singlebeam data files as outlined in Section 5.2.2 of the HSSD.

Each generated BAG file also has a separate eXtensible Markup Language (XML) metadata file which **SABER** creates as the BAG is generated. **SABER** automatically populates each generated metadata file with data specific to the BAG such as the UTM projection, bounding coordinates, horizontal datum, and node spacing. The generated XML metadata files were edited to include additional information such as the responsible party, name of the dataset, person responsible for input data, and other information specific to the project and survey sheet which was not automatically populated by **SABER**.

The edits made to each metadata file were then written back to each corresponding BAG file using the **Update BAG Metadata XML** utility in **SABER**. Although any or all of the fields within the generated metadata files can be edited within a text editor program, **SABER** does not allow the BAG files to be updated with any metadata XML file where the values in the automatically populated fields have been changed from the values stored in the BAG files. To ensure all metadata information were correctly edited, updated, written back to the BAG files, and stored within the BAG files each BAG metadata XML file was re-exported for QC purposes.

The **Compare BAG to PFM** utility in **SABER** was used for QC of data within each generated BAG layer. This tool provided the ability to compare all surfaces from each node within the BAG files to the surface values of the same node within the PFM. This was done to ensure that all values are exported and generated correctly in the BAG files, and that no values were dropped during the generation of the BAG files.

Along with the standard deliverable BAG files for this project, separate BAG files were generated for areas throughout the survey with significant features, as required by the HSSD. These feature area BAG files were generated from the feature area CUBE PFM grids and include CUBE Depth and Hypothesis Final Uncertainty surfaces. Half-meter grid resolution was used for feature BAG files to comply with the coverage and resolution requirements of the Object Detection Coverage, Section 5.2.2.1, of the HSSD.

B.2.6 S-57 Feature File

Included with each sheet's delivery is a S-57 feature file made in accordance with the IHO Special Publication No. 57, *"IHO Transfer Standard for Digital Hydrographic Data"*, Edition 3.1, (IHO S-57) and Section 8.2 of the HSSD.

The S-57 feature file was generated through **SABER** using the SevenCs ECDIS (Electronic Chart Display and Information System) Kernel. The ECDIS Kernel is based on the IHO S-57 as well as the IHO Special Publication S-52 *"Specifications for Chart Content and Display Aspects of ECDIS"* (S-52); which details the display and content of digital charts as well as establishing presentation libraries. Leidos implements the

SevenCs ECDIS Kernel as a building block, the Kernel maintains the presentation libraries used to create the S-57 (.000) feature files and retains the IHO requirements, while Leidos maintains the source code which drives the use of the SevenCs ECDIS Kernel so that S-57 feature files can be created through **SABER**.

Leidos modified the **SABER** S-57 libraries to allow for the addition of the NOAA Extended Attributes, as specified in Appendix 8 of the HSSD. Each feature within the S-57 Feature File has the availability to populate any of the Extended Attributes documented within the HSSD. When appropriate the NOAA Extended Attributes have been classified for each feature within the S-57 Feature File.

As stated in the Section 8.2 of the HSSD, navigational aids that are maintained by the U.S. Coast Guard are not included with the final S-57 feature file. When aids to navigation are privately maintained the resulting feature was included in the respective sheet's final S-57 feature file. All aids to navigation that fell within the bounds of Project OPR-B310-KR1-13 are discussed within the DR for the appropriate sheet.

Feature depths were attributed within the S-57 feature file (.000) as value of sounding (VALSOU) and were maintained to millimeter precision. All features addressed within each sheet were retained within that sheet's respective S-57 feature file. For all features, the requirements from the IHO S-57 standard were followed, unless otherwise specified in Section 8.2 of the HSSD. Also, following the IHO S-57 standard and Section 8.2 of the HSSD, each sheet's S-57 feature file is delivered in the WGS84 datum and is unprojected with all units in meters.

In addition, the Feature Correlator Sheets were exported as JPEG files and included under the NOAA Extended Attribute "images".

Each sheet's S-57 feature file was subjected to ENC validation checks using Jeppesen's **dKart Inspector** and QC'd with **dKart Inspector**, CARIS **Easy View**, and SevenCs **SeeMyDENC**.

As requested by NOAA, AHB also generated a supplemental S-57 file for each sheet to display the mooring fields and corresponding side scan contacts Leidos made to delineate the bounds of mooring fields. The mooring field area was attributed as a Mooring/Warping Facility S-57 object (MORFAC) while the cartographic symbol object ($CSYMB) was used for all contacts Leidos had set on a mooring. These $CSYMB data points are not delivered in the final S-57 Feature File or the Side Scan Sonar Contact S-57 File. Whereas the MORFAC object is carried through in the final S-57 Feature File and Side Scan Sonar Contact S-57 file.

For spatial reference, the meta-objects provided in the final S-57 Feature File are also in the Mooring Field S-57 file.

B.2.7 Multibeam Ping and Beam Flags

Flags in **SABER** come in four varieties: Ping flags, Beam flags, PFM depth record flags, and PFM bin flags. Ping and beam flags are specific to the GSF files, where they are used to attribute ping records and the individual beams of each ping record. Beam flags are used to describe why soundings are invalid and rejected, how they were edited, if they meet various cutoff criteria, etc. These same flags also contain descriptors used to indicate that a sounding is a selected sounding and why it is a selected sounding (feature, designated sounding, least depth, etc.).

There are sixteen bits available in GSF for ping flags so the flags are written to the files using 16-bit binary numbers. The ping flag bits are separated into two groups: Ignore bits and Informational bits. Bits zero through eleven are the Ignore bits. If bit zero is set, the ping is flagged as invalid. Bits 1 through 11 specify the reason(s) why the ping was flagged invalid. If only bit zero is set, the ping is flagged due to no bottom detection. However, if any of the bits 1 through 11 are set, bit zero will also be set. Bits 12 through 15 are Informational flags, and they describe actions that have been performed on a ping, such as applying delayed heave or a tide corrector. Bits 12 through 15 can be set regardless of whether or not any of bits zero through 11 are set. Bit 13 defines whether or not the GPS-based vertical control was applied. Bits 14 and 15 are used in conjunction with each other to describe the source of the tide corrector applied to a ping.

Eight bits are available in the GSF file for beam flags. The eight bit beam flag value stored in GSF files is divided into two four-bit fields. The lower-order four bits are used to specify that a beam is to be ignored, where the value specifies the reason the beam is to be ignored. The higher-order four bits are used to specify that a beam is selected, where the value specifies the reason why the beam is selected.

Leidos and CARIS have collaborated to provide the ability to import multibeam GSF files into CARIS. Table B-3 represents commonly used definitions for these GSF beam flags, as well as their mapping to CARIS flag codes. Table B-4 represents commonly used definitions for these GSF ping flags, as well as their mapping to CARIS flag codes.

Note that there is not a one-for-one match between CARIS Profile and Depth flags and GSF Ping and Beam flags. Therefore, upon the import of multibeam GSF files into CARIS, GSF defined flags such as: delayed heave applied, GPSZ applied, the applied tide type in use, and Class1 not being met are not available in CARIS. As detailed in Table B-3 and Table B-4, no flag is applied in CARIS to the HDCS files, upon import from GSF, for these GSF ping and beam flags.

Table B-8. Mapped GSF Beam Flags and CARIS Flag Codes

GSF Beam Flags		CARIS HIPS Flag	
Bitmask	Comments	Name	Comments
0000 0010	Selected sounding, no reason specified.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0000 0110	Selected sounding, it is a least depth.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0000 1010	Selected sounding, it is a maximum depth.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0001 0000	Does NOT meet Class1 (informational flag).	No flag to be applied to HDCS files upon import from GSF.	
0001 0010	Selected sounding, average depth.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0010 0010	Selected sounding, it has been identified as a feature.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0100 0010	Spare bit Field.	N/A	
1000 0010	Selected sounding, it has been identified as a designated sounding.	PD_DEPTH_DESIGNATED_MASK	Indicates that the user has explicitly selected this sounding as a designated sounding.
0000 0001	Null Invalidated – No detection was made by the sonar.	PD_DEPTH_REJECTED_MASK	Indicates that this sounding has been rejected. The reason may or may not be indicated by the other bits. This bit is inherited from the Observed Depths file but can be changed by HDCS.
0000 0101	Manually edited (i.e., MVE).	PD_DEPTH_REJECTED_BY_SWATHED_MASK	Indicates that the sounding has been rejected in the swath editor. Soundings which are rejected in this manner are not visible in older versions of HDCS, but are visible in the newer PC based software.
0000 1001	Filter edited.	PD_DEPTH_REJECTED_MASK	Indicates that this sounding has been rejected. The reason may or may not be indicated by the other bits. This bit is inherited from the Observed Depths file but can be changed by HDCS.
0010 0001	Does NOT meet Class2.	PD_DEPTH_REJECTED_MASK	Indicates that this sounding has been rejected. The reason may or may not be indicated by the other bits. This bit is inherited from the Observed Depths file but can be changed by HDCS.
0100 0001	Resolution Invalidated – Exceeds maximum footprint.	PD_DEPTH_REJECTED_MASK	Indicates that this sounding has been rejected. The reason may or may not be indicated by the other bits. This bit is inherited from the Observed Depths file but can be changed by HDCS.
1000 0001	This beam is to be ignored, it exceeds the IHO standards for Horizontal OR Vertical error.	PD_DEPTH_REJECTED_BY_TOTAL_PROPAGATION_ERROR (TPE)	Indicates that the reason for rejection was because the beam failed Total Propagation Error (TPE).

Table B-9. Mapped GSF Ping Flags and CARIS Flag Codes

GSF Ping Flags		CARIS HIPS Flag	
Bitmask	Comments	Name	Comments
0000 0000 0000 0001	IGNORE PING	PD_PROFILE_REJECTED_MASK	Indicated that the profile has been rejected. It implies that all soundings within the profile are also rejected.
0000 0000 0000 0011	OFF LINE PING	PD_PROFILE_REJECTED_MASK	Indicated that the profile has been rejected. It implies that all soundings within the profile are also rejected.
0000 0000 0000 0101	BAD TIME	PD_PROFILE_REJECTED_MASK	Indicated that the profile has been rejected. It implies that all soundings within the profile are also rejected.
0000 0000 0000 1001	BAD POSITION	PD_PROFILE_BAD_NAVIGATION_MASK	Indicates that the profile is rejected because of bad navigation reading. This flag is not currently being used.
0000 0000 0001 0001	BAD HEADING	PD_PROFILE_BAD_GYRO_MASK	Indicates that the profile is rejected because of bad gyro reading. This flag is not currently being used.
0000 0000 0010 0001	BAD ROLL	PD_PROFILE_BAD_ROLL_MASK	Indicates that the profile is rejected because of bad roll reading. This flag is not currently being used.
0000 0000 0100 0001	BAD PITCH	PD_PROFILE_BAD_PITCH_MASK	Indicates that the profile is rejected because of bad pitch reading. This flag is not currently being used.
0000 0000 1000 0001	BAD HEAVE	PD_PROFILE_BAD_HEAVE_MASK	Indicates that the profile is rejected because of bad heave reading. This flag is not currently being used.
0000 0001 0000 0001	BAD DEPTH CORRECTOR	PD_PROFILE_BAD_DRAFT_MASK	This is set by the merge function, and indicates that the profile is rejected because vessel draft cannot be interpolated.
0000 0010 0000 0001	BAD TIDE CORRECTOR	PD_PROFILE_BAD_TIDE_MASK	Indicates that the profile is rejected because of bad tide reading. This flag is not currently being used.
0000 0100 0000 0001	BAD SVP	PD_PROFILE_BAD_SVP_MASK	This is a mirror of the bit in the observed depths file, where the SV correction functions are implemented. It indicates that the profile is rejected because of interpolation errors during the SV correction procedure.
0000 1000 0000 0001	NO POSITION	PD_PROFILE_REJECTED_MASK	Indicates that the profile has been rejected. It implies that all soundings within the profile are also rejected.
0001 0000 0000 0000	DELAYED HEAVE APPLIED	No flag to be applied to HDCS files upon import from GSF.	
0010 0000 0000 0000	GPSZ APPLIED	No flag to be applied to HDCS files upon import from GSF.	
0100 0000 0000 0000	Combine with bit 15 represents applied tide type.	No flag to be applied to HDCS files upon import from GSF.	
1000 0000 0000 0000	Combine with bit 14 represents applied tide type.	No flag to be applied to HDCS files upon import from GSF.	

B.3 SIDE SCAN SONAR DATA PROCESSING

Side scan sonar data processing was a multi-step process consisting of updating the navigation and heading in the XTF files, running Automatic Contact Detection (ACD), applying the Trained Neural Network, and reviewing the imagery, contacts, and data coverage.

In January 2012, Leidos released **SABER** 5.0 which included software for side scan data processing. These side scan data processing programs were developed and thoroughly tested at Leidos Newport, RI. Some of these programs included in **SABER** 5.0 were **Automatic Contact Detection** (**ACD**), **Automatic Detection Classification**, **Imagery Review**, **Contact Review**, and **XML Contact Management**.

B.3.1 Side scan Navigation Processing

The **SABER Navup** routine was used to re-navigate the side scan towfish in order to provide more accurate towfish positions. This routine replaced the towfish positions (sensor X and sensor Y fields) recorded in the original side scan XTF file with the final towfish positions derived from the catenary data files recorded during acquisition by **ISS-2000**. The Navup routine also computed and applied a unique heading for each ping record (as opposed to the 1 Hz position and heading data recorded during data acquisition). Each record in the catenary file included:

- Time
- Towfish position
- Cable out
- Layback
- Towfish velocity
- Towfish heading
- Towfish depth
- Tow angle

All side scan data are delivered with completely corrected side scan sonar positions. Towfish track plots were generated by extracting the towfish position at 1-second intervals for quality control of the **Navup** process.

B.3.2 Side scan Contact Detection

Side scan contact detection was performed using the **Automatic Contact Detection** (**ACD**) program within **SABER**.

The **Automatic Contact Detection** program was run to identify seafloor contacts from the side scan sonar data and also included processes to correct the bottom tracking (towfish altitude) in each XTF file. The software was designed to detect a contact at least one cubic meter in size. For each detection, parameters such as shape and texture were extracted as well as measurement of the length, width and height. This process consisted of three major stages, altitude correction (i.e. bottom tracking), contact detection, and Trained Neural Network application.

B.3.2.1 Bottom Tracking

The **Automatic Contact Detection** software started with a bottom-tracking routine that was developed to determine if the value stored in the altitude field for each ping is accurate. If not, the program attempted to determine the true bottom and populated the altitude field with a new value. If the automatic bottom-tracking algorithm was uncertain of the quality of the bottom detection for a particular time period, it provided a report listing those times. The reviewer would use the report as the basis for manually fixing the bottom tracking.

B.3.2.2 Contact Detection

The **Automatic Contact Detection** software used a split-window normalization algorithm commonly referred to as constant false alarm rate (CFAR) detection. In order to avoid thousands of false detections in sand-wave fields, the detection processing included a two-dimensional median wave-number filter to suppress sand waves and other periodic background interference before shadow processing. This process was done using a detection parameter file (dpf) input into **SABER**. With the multi vessel operation using both different side scan sonars as well as different range scales in order to accurately generate detections, Leidos established three different detection parameter files. These are detailed in Table B-10 through Table B-12. A peak and shadow score were calculated independently, and then combined, to produce an overall total contact score. If the overall score was above a defined threshold, then a detection was triggered. This process ran independently on all channels within the XTF file.

The image processing phase then processed each detection that was generated. This phase extracted parameters from each detection (e.g. shape and texture), normalized the parameters and automatically measured the length, width, and height of each detection. Once the parameters are extracted from the images associated with each detection, the program normalized and prioritized those parameters for use in the subsequent neural network phase which classified the detections.

Table B-10. Detection Parameters File Used For Klein 3000 50-meter Range Scale

General Detection Parameter	Value	Units
Pings to Process	2048	Pings
Detection Box Width	200	Samples
Detection Box Length	40	Pings
Max Number of Detections	25	Detections
Bottom Track Box Height	10	Pings
Bottom Track Box Width	10	Samples
Bottom Track Box threshold	10	
Bottom Track Alert Threshold	10	
Bottom Track Alert Interval	10	
Reject Columns	2	% Across Track Samples to Clip
Geometric Correction Limit	2.5	

Detect Ping Difference	10		Pings
Detect Sample Difference	50		Samples
Frequency Parameter	**Low Frequency Value**	**High Frequency Value**	**Units**
Peak Noise Detect Length	10	10	Pings
Peak Noise Detect Width	49	49	Samples
Peak Noise Mask	25	25	Pings
Peak Min Threshold	2.2	1.5	Multiplier
Peak Max Length	5	5	Pings
Peak Min Length	2	2	Pings
Shadow Noise Detect Length	10	10	Pings
Shadow Noise Detect Width	24	24	Samples
Shadow Noise Mask	25	25	Pings
Shadow Max Threshold	0.75	0.70	Multiplier
Shadow Detect Length	3	3	Pings
Shadow Detect Width	27	27	Samples
Detect Search Box Length	5	5	Pings
Detect Search Box Width	11	11	Samples
Area Detect Threshold	88	100	
Hamming Filter Width	30	30	Samples
Shadow Score Width	3	3	Samples

Table B-11. Detection Parameters File Used For Klein 3000 25-meter Range Scale

General Detection Parameter	**Value**		**Units**
Pings to Process	2048		Pings
Detection Box Width	200		Samples
Detection Box Length	40		Pings
Max Number of Detections	25		Detections
Bottom Track Box Height	10		Pings
Bottom Track Box Width	10		Samples
Bottom Track Box threshold	15		
Bottom Track Alert Threshold	10		
Bottom Track Alert Interval	10		
Reject Columns	3.5		% Across Track Samples to Clip
Geometric Correction Limit	2.5		
Detect Ping Difference	10		Pings
Detect Sample Difference	50		Samples
Frequency Parameter	**Low Frequency Value**	**High Frequency Value**	**Units**
Peak Noise Detect Length	10	10	Pings
Peak Noise Detect Width	49	49	Samples
Peak Noise Mask	25	25	Pings

Peak Min Threshold	2.2	1.5	Multiplier
Peak Max Length	5	5	Pings
Peak Min Length	2	2	Pings
Shadow Noise Detect Length	10	10	Pings
Shadow Noise Detect Width	24	24	Samples
Shadow Noise Mask	25	25	Pings
Shadow Max Threshold	0.75	0.70	Multiplier
Shadow Detect Length	3	3	Pings
Shadow Detect Width	27	27	Samples
Detect Search Box Length	5	5	Pings
Detect Search Box Width	11	11	Samples
Area Detect Threshold	88	100	
Hamming Filter Width	30	30	Samples
Shadow Score Width	3	3	Samples

Table B-12. Detection Parameters File Used For Klein 3900 30-meter Range Scale

General Detection Parameter	**Value**		**Units**
Pings to Process	2048		Pings
Detection Box Width	200		Samples
Detection Box Length	40		Pings
Max Number of Detections	25		Detections
Bottom Track Box Height	10		Pings
Bottom Track Box Width	10		Samples
Bottom Track Box threshold	20		
Bottom Track Alert Threshold	10		
Bottom Track Alert Interval	10		
Reject Columns	2.5		% Across Track Samples to Clip
Geometric Correction Limit	2.5		
Detect Ping Difference	10		Pings
Detect Sample Difference	50		Samples
Frequency Parameter	**Low Frequency Value**	**High Frequency Value**	**Units**
Peak Noise Detect Length	10	10	Pings
Peak Noise Detect Width	49	49	Samples
Peak Noise Mask	25	25	Pings
Peak Min Threshold	1.5	1.5	Multiplier
Peak Max Length	5	5	Pings
Peak Min Length	2	2	Pings
Shadow Noise Detect Length	10	10	Pings
Shadow Noise Detect Width	24	24	Samples
Shadow Noise Mask	25	25	Pings
Shadow Max Threshold	0.70	0.70	Multiplier

Shadow Detect Length	3	3	Pings
Shadow Detect Width	27	27	Samples
Detect Search Box Length	5	5	Pings
Detect Search Box Width	11	11	Samples
Area Detect Threshold	100	100	
Hamming Filter Width	30	30	Samples
Shadow Score Width	3	3	Samples

B.3.2.3 Apply Trained Neural Network File

Once the detections were selected, a Trained Neural Network file was applied to classify the detections as either a contact or clutter (false alarm). For this project, the neural network file used was *Combined_all_NN_ratio_60a_40r_par20_200.nnt.* It contained data from three previous NOAA sheets:

- Sheet F H11241 (2003) Klein 2000
- Sheet H H11455 (2005) Klein 3000
- Sheet R H12094 (2010) Klein 3000

These sheets provided a broad range of data across two sonar types and various bottom types. The Neural Network file was created by taking a random selection of detections from each sheet and creating a ratio of 60 percent accepted detections (true detections) and 40 percent rejected detections (false alarms). The number of image parameters the Neural Network used was determined by two primary criteria, the Mahalanobis distance (Figure B-1) and pair-wise covariance. The Mahalanobis distance is a measure of the statistical distance between two classes based simply on their normal distributions; while the covariance is a measure of how similar the two parameters are. After numerous test cycles 20 parameters were chosen.

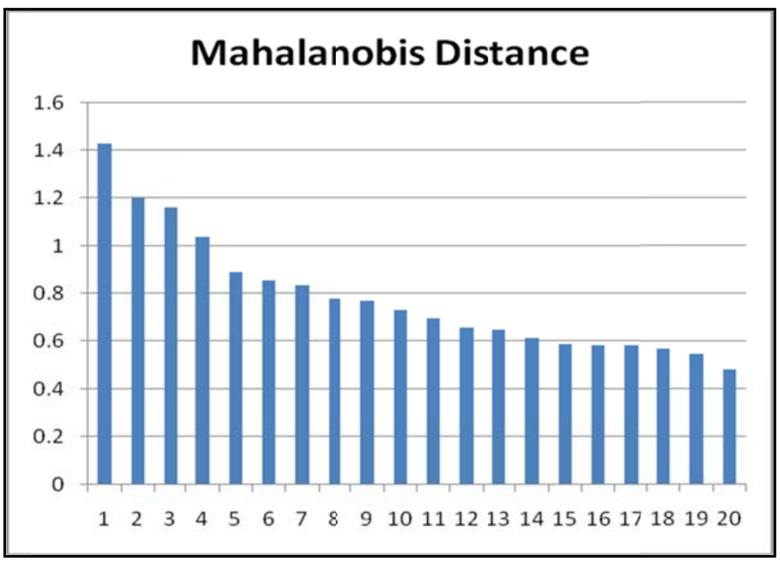

Figure B-1. Mahalanobis Distance of Top Twenty Parameters

When the Trained Neural Network file was applied to the detection files, the program assigned a network activation number to each detection. The network activation number ranged between zero and one, with zero being clutter and one being a contact. For values that fall in between zero and one, a user assigned value (decision method) determines which detections are classified as contacts (equal to or greater than the decision method) or as clutter (below decision method). The decision method value used for this project was 0.90. This value was determined during the alpha and beta software test cycles by analyzing numerous pre-processed datasets. The beta distributions fit to the network activations from the entire neural network training dataset were plotted in Figure B-2 with the decision method in green. This shows that, by using a decision method of 0.90, most of the detections classified as contacts will fall above this value.

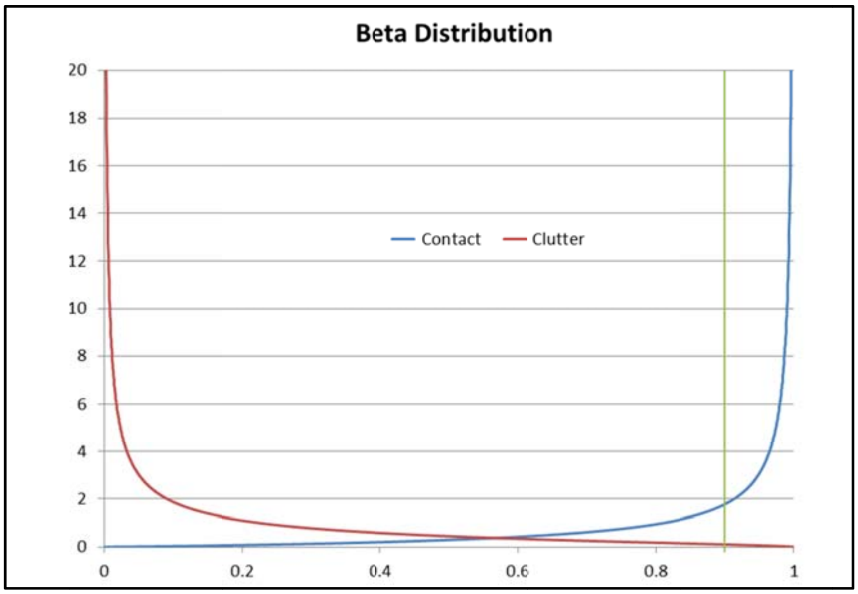

Figure B-2. Decision Method Based on Beta Distributions.

B.3.3 Side scan Data Quality Review

After each survey day, a hydrographer reviewed the side scan sonar data for quality, bottom tracking, and contacts using the **SABER's Imagery Review** and **Contact Review** programs. Within **Imagery Review**, the detections were overlain on the side scan sonar record. The side scan data within **Imagery Review** was down sample using the Average Display Method. This was chosen because it provided the best general-purpose review settings. Down sampling is necessary because the number of pixels displayed is constrained by the width of the display window and the screen resolution. During this review, the hydrographer assessed the overall quality of the data and defined any holidays in the data where the quality was insufficient to clearly detect seafloor contacts across the full range scale. The times and descriptions for any defined data holidays were entered into a Side scan Review Log which was created and maintained for each sheet of the project. The times of all noted side scan data gaps were also incorporated into the side scan data time window files that were then used to depict the data gap within the applicable side scan coverage mosaic as discussed in Section A.7. Data holidays were generally characterized by:

- Surface noise (vessel wakes, sea clutter, and/or waves)
- Towfish motion (yaw and heave)
- Acoustic noise
- Density layers (refraction)
- Electrical noise

The Side scan Review Log for each sheet was maintained throughout final data processing. It incorporated all of the relevant information about each side scan data file, including the line begin and line end times, survey line name, corresponding multibeam file name(s), line azimuth, and any operator notes made during data acquisition. System-status annotations were recorded in the logs at the beginning of survey operations in each sheet, upon returning to the survey area, and at the JD rollover of each continuous survey day. These system-status annotations included; the mode of tuning (auto tuning was used throughout all survey operations), the tow point (The A-fame was used throughout all survey operations), the side scan range scale setting, the watchstander's initials, the side scan model in use, whether or not a depressor was in use on the side scan, weather conditions and sea state. These and any other necessary annotations were continuously updated throughout survey operations as needed in accordance with Section 8.3.3 of HSSD. Each sheet's Side scan Review Log is included in Separates I of the sheet's Descriptive Report.

B.3.4 Side scan Contact Analysis

During side scan data review, the hydrographer used the **Contact Review** program to review each detection and was able to either accept it as a real contact or reject it (i.e. contacts created on fish or multiple contacts on a large object). The hydrographer could also override the automatic measurements of the contact's length, width and height or generate new contacts. Selected contacts and pertinent information for each contact was documented in the Side scan Review Log. Significant side scan contacts were chosen based on size and height, or a unique sonar signature. In general, contacts with a computed height greater than 50 centimeters were typically selected, however this was also depth dependent. Contacts with a unique sonar signature (e.g. size, shape, and reflectivity) were typically selected regardless of height. Contacts made within **SABER** were saved to an XML file. Contact specific information including year, date, time, position, fish altitude, slant range, contact measurements, and any remarks were contained in the XML file. These data can also be found within the delivered Side Scan Sonar Contacts S-57 file for each sheet.

The **SABER Contact Review** program does not down sample the side scan data when the contacts are displayed. The contact is always opened by the program at full resolution, so the hydrographer can choose to zoom in or out to review the contact. When measuring contacts within Contact Review, the length is always the along track dimension and the width is always the across track dimension. Therefore it is possible to have a width measurement that is longer than the length measurement.

Some of the guidelines followed by the hydrographer for contact generation and documentation included the following. Wrecks and large objects were positioned at their highest point based on the observed acoustic shadow. Similarly, contacts for debris fields were positioned on the tallest measured object in the debris field. Contacts were also made on exposed cables, pipelines, and sewer outfalls, regardless of height. In addition to contacts, the Side Scan Review Log also includes entries for many non-significant seafloor objects (e.g., fishing gear, small objects, etc.) that were identified during the side scan data review.

Bathymetric feature and side scan contact correlation was conducted in **SABER**. The XML file was viewed in **SABER** as a separate data layer along with the PFM layer and the multibeam feature file (CNT). By comparing the bathymetry with the side scan contact data, both datasets could be evaluated to determine the significance of an object and the potential need to create additional side scan contacts or bathymetric features. This correlation updated the CNT file with the type of feature (obstruction, wreck, etc.) and the XML file with the correlated feature number and depth.

SABER generated side scan contact images for each contact within the XML and they are delivered in two different ways. The first is through the Side scan Sonar Contacts S-57 file utilizing the NOAA Extended Attribute “images” field. The second involves only side scan contacts that have been correlated to a multibeam feature; in this case, the images are visible in the Feature Correlator sheets attached to the S-57 feature file utilizing the NOAA Extended Attribute “images” field.

B.3.5 Side scan Sonar Contacts S-57 File

Leidos also generated a S-57 file for each sheet to display the side scan sonar contacts. The Side Scan Sonar Contacts S-57 file (.000) was generated through the same process used to build each sheet’s final S-57 Feature file, described in Section B.2.6, except with side scan contact information incorporated instead of multibeam feature information.

Within the Side scan Sonar Contacts S-57 file, side scan contacts were represented using an object from the Cartographic Object Classes: Cartographic Symbol ($CSYMB). Side scan contacts in the final contact XML for each sheet were delivered in the respective Side Scan Sonar Contacts S-57 file, regardless of the contact’s significance. The information field (INFORM) of each cartographic symbol provides specific information such as the contact name, length, width, height, shadow length, range scale, slant range, altitude, and whether or not the contact was correlated to a bathymetric feature, and the survey line name. Also for contacts correlated to a bathymetric feature or object in the final S-57 Feature File, the charting recommendations for the feature or object are listed under the NOAA Extended attribute, recommendations (recomd) field, as it appears in the sheet's final S-57 Feature File. The NOAA Extended Attribute “images” field of each cartographic symbol details an associated JPEG image for the side scan contact it represents.

For spatial reference, the meta-objects provided in the final S-57 Feature File are also in the Side Scan Sonar Contacts S-57 file.

An additional supplemental Cartographic Symbol S-57 file of contact that were designated as moorings is also delivered. This S-57 file contains individual mooring side scan contacts and a polygon delineating the extents of the mooring field. The individual contacts are not contained in the normal Side Scan Contact S-57 File, however the mooring field polygon is contained in that S-57 file.

B.3.6 Side scan Coverage Analysis

The Project Instructions required 200% side scan coverage for water depths greater than four meters, and 100% side scan coverage for water depths from two to four meters. The 200% side scan coverage was verified by generating two separate 100% coverage mosaics. To accomplish this, a time window file listing the times of all valid online side scan data was created along with separate side scan file lists for the first and second 100% coverage mosaics. Using **SABER**, the time window file and the side scan file lists were then used to create one-meter cell size mosaics in accordance with Section 8.3.1 of the HSSD. The first and second 100% coverage mosaics were reviewed independently using tools in **SABER** to verify data quality and swath coverage. During data acquisition, preliminary first and second 100% coverage mosaics were also used to plan additional survey lines to fill in any data gaps. All final delivered first and second 100% coverage mosaics are determined to be complete and sufficient to meet the Project Instructions for side scan sonar coverage, unless otherwise noted in a sheet's Descriptive Report.

Each 100% coverage mosaic is delivered as a geo-referenced image (an image file [.tif] and a corresponding world file [.tfw]).

C. CORRECTIONS TO ECHO SOUNDINGS

The data submitted are fully corrected with uncertainties associated with each sounding. Therefore, the CARIS vessel file will be all zeros.

Figure C-1 shows the 2013 *M/V Atlantic Surveyor* sensor configuration and the vessel offsets for the RESON 7125 SV. The 2013 vessel offsets are tabulated in Table C-1. All measurements are in meters. The RESON 7125 SV transducer was hull-mounted approximately amidships, just port of the keel. Offset measurements were made from the POS/MV IMU to the acoustic center of the RESON 7125 SV transducer. See Appendix 1 for details on the vessel offsets survey.

Figure C-2 shows the *R/V Oyster Bay* sensor configuration and the vessel offsets for the Odom CVM as installed from 19 August 2013 through 25 August 2013. Figure C-3 shows the *R/V Oyster Bay* sensor configuration and the vessel offsets for the Odom CVM as installed from 27 August 2013 through 27 October 2013. These vessel offsets are tabulated in Table C-2 and Table C-3. All measurements are in meters. For both installations, the Odom CVM transducer was pole-mounted approximately amidships, on the port side. Offset measurements were made from the POS/MV IMU to the acoustic center of the Odom transducer. See Appendix 1 for details on the vessel offsets survey.

Figure C-4 shows the 2013 *R/V Oyster Bay* sensor configuration and the vessel offsets for the RESON 8101 ER. The 2013 vessel offsets are tabulated in Table C-4. All measurements are in meters. The RESON 8101 ER transducer was pole-mounted approximately amidships, on the port side. Offset measurements were made from the POS/MV IMU to the acoustic center of the RESON 8101 ER transducer. See Appendix 1 for details on the vessel offsets survey.

Figure C-5 shows the 2013 *R/V Henry Hudson* sensor configuration and the vessel offsets for the RESON 8101 ER. The 2013 vessel offsets are tabulated in Table C-5. All measurements are in meters. The RESON 8101 ER transducer was pole-mounted approximately amidships, on the port side. Offset measurements were made from the POS/MV IMU to the acoustic center of the RESON 8101 ER transducer. See Appendix 1 for details on the vessel offsets survey.

The Leidos **ISS-2000** and the POS/MV software utilize a coordinate system where "Z" is considered to be positive down, "X" is considered to be positive forward, and "Y" is considered to be positive to starboard. Table C-1 through Table C-5 document which sensor offsets were entered into the POS/MV (offsets referenced to the IMU) or **ISS-2000** (offsets referenced to the sonar acoustic center) software. All final data products from any given sensor utilize this same coordinate system.

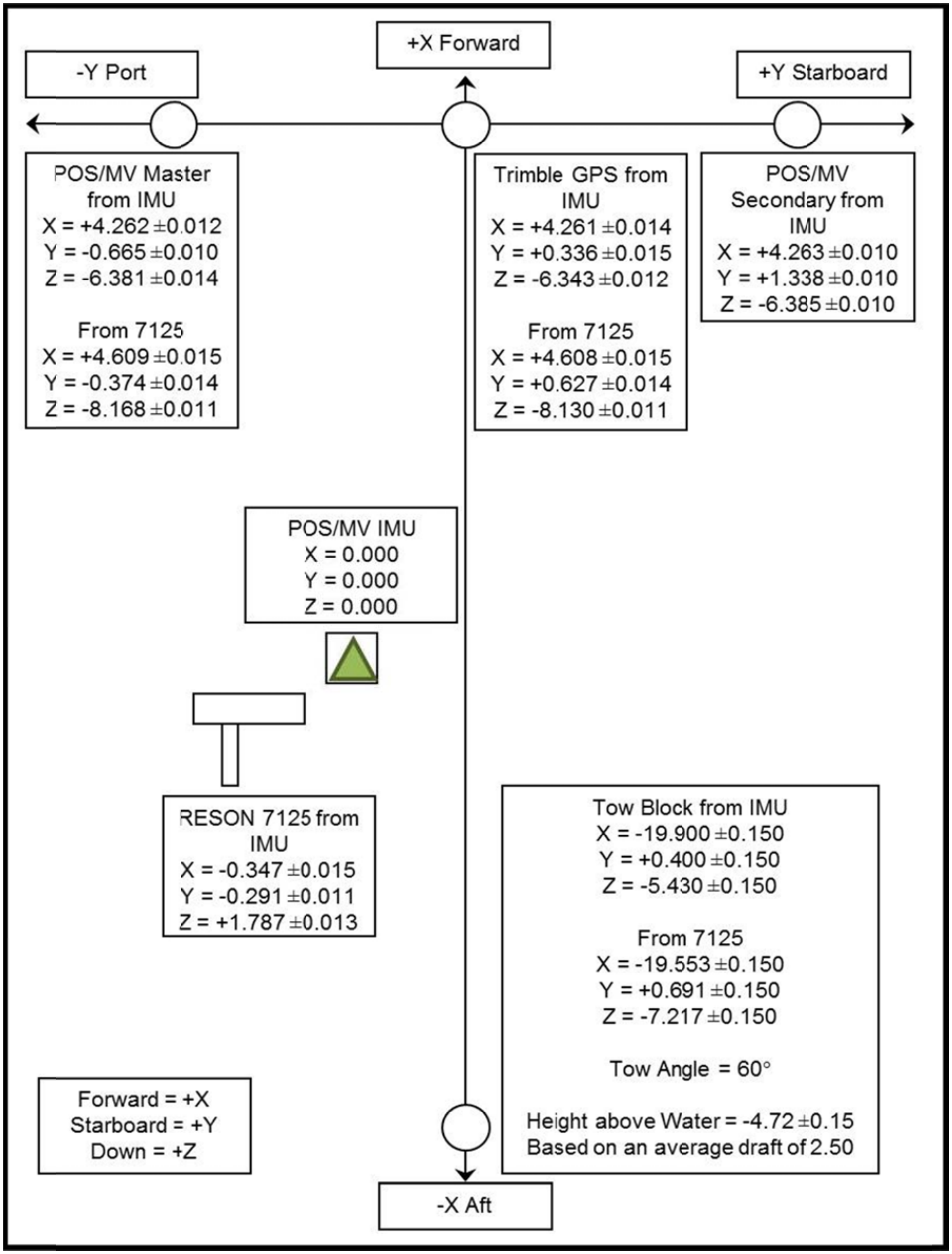

Figure C-1. 2013 Configuration and Offsets of *M/V Atlantic Surveyor* Sensors for the RESON 7125 SV (measurements in meters with 1-sigma uncertainty)

Table C-1. 2013 *M/V Atlantic Surveyor* Antenna and RESON 7125 SV Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point (measurements in meters with 1-sigma uncertainty)

Sensor	Offset in ISS-2000		Offset in POS/MV	
Multibeam RESON 7125 Transducer Hull Mount			X	-0.347 ±0.015
			Y	-0.291 ±0.011
			Z	+1.787 ±0.013
Reference to Heave			X	0.00
			Y	0.00
			Z	0.00
Reference to Vessel			X	-0.347 ±0.015
			Y	-0.291 ±0.011
			Z	+1.787 ±0.013
POS/MV GPS Master Antenna			X	+4.262 ±0.012
			Y	-0.665 ±0.010
			Z	-6.381 ±0.014
Trimble GPS Antenna From Transducer	X	+4.608 ±0.015		
	Y	+0.627±0.014		
	Z	-8.130 ±0.011		
A-Frame Tow Block (X and Y from Reson 7125 Transducer. Z is height above water.)	X	-19.553 ±0.150		
	Y	+0.691 ±0.150		
	Z	-4.720 ±0.150		

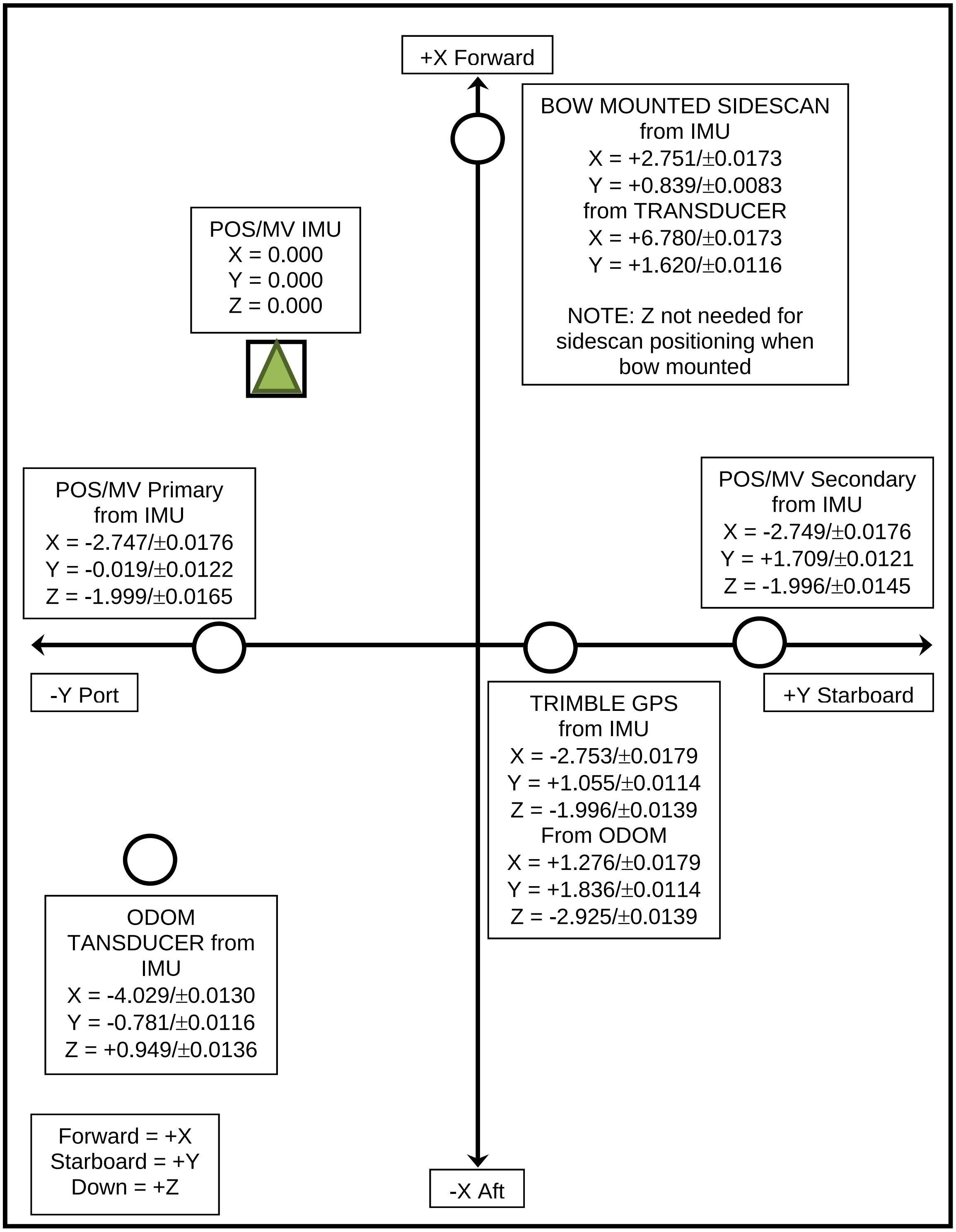

Figure C-2. 19 August 2013 through 25 August 2013 Configuration and Offsets of *R/V Oyster Bay* Sensors for the ODOM CVM (measurements in meters with 1-sigma uncertainty)

Table C-2. 19 August 2013 through 25 August 2013 *R/V Oyster Bay* Antenna and Odom CVM Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point (measurements in meters with 1-sigma uncertainty)

Sensor	Offset in ISS-2000		Offset in POS/MV	
Odom Transducer Side Mount (Reference to Vessel Lever Arm)			X	-4.029±0.0130
			Y	-0.781±0.0116
			Z	+0.949±0.0136
Reference to Center of Rotation Lever Arm			X	-1.663±0.0100
			Y	+0.839±0.0081
			Z	0.000±0.0100
Reference to Sensor 1Lever Arm			X	-4.029±0.0130
			Y	-0.781±0.0116
			Z	+0.949 ±0.0136
POS/MV GPS Master Antenna (Reference to Primary GPS Lever Arm)			X	-2.747±0.0176
			Y	-0.019±0.0122
			Z	-1.999±0.0165
Trimble GPS Antenna From Transducer	X	+1.276±0.0179		
	Y	+1.836±0.0114		
	Z	-2.925 ±0.0139		
Bow Mounted Side scan (X and Y from Odom Transducer. Z is not needed for positioning bow mounted side scan)	X	+6.780±0.0173		
	Y	+1.620±0.0116		
	Z	N/A		

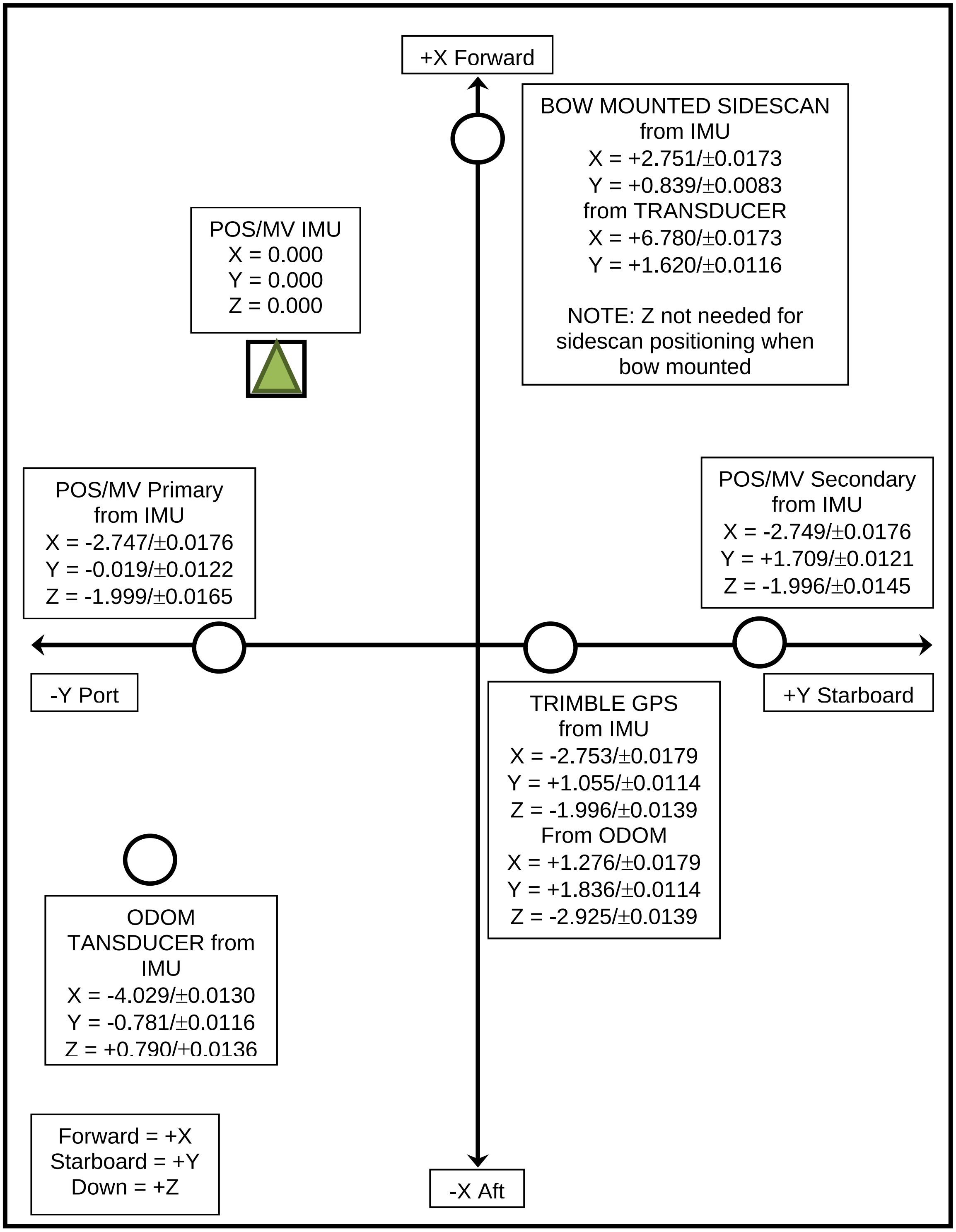

Figure C-3. 27 August 2013 through 27 October 2013 Configuration and Offsets of *R/V Oyster Bay* Sensors for the ODOM CVM (measurements in meters with 1-sigma uncertainty)

Table C-3. 27 August 2013 through 27 October 2013 *R/V Oyster Bay* Antenna and Odom CVM Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point (measurements in meters with 1-sigma uncertainty)

Sensor	Offset in ISS-2000		Offset in POS/MV	
SinglebeamODOM Transducer Side Mount (Reference to Vessel Lever Arm)			X	-4.029±0.0130
			Y	-0.781±0.0116
			Z	+0.790±0.0136
Reference to Center of Rotation Lever Arm			X	-1.663±0.0100
			Y	+0.839±0.0081
			Z	0.000±0.0100
Reference to Sensor 1Lever Arm			X	-4.029±0.0130
			Y	-0.781±0.0116
			Z	+0.790 ±0.0136
POS/MV GPS Master Antenna (Reference to Primary GPS Lever Arm)			X	-2.747±0.0176
			Y	-0.019±0.0122
			Z	-1.999±0.0165
Trimble GPS Antenna From Transducer	X	+1.276±0.0179		
	Y	+1.836±0.0114		
	Z	-2.925 ±0.0139		
Bow Mounted Side scan (X and Y from Odom Transducer. Z not needed for positioning bow mounted side scan)	X	+6.780±0.0173		
	Y	+1.620±0.0116		
	Z	N/A		

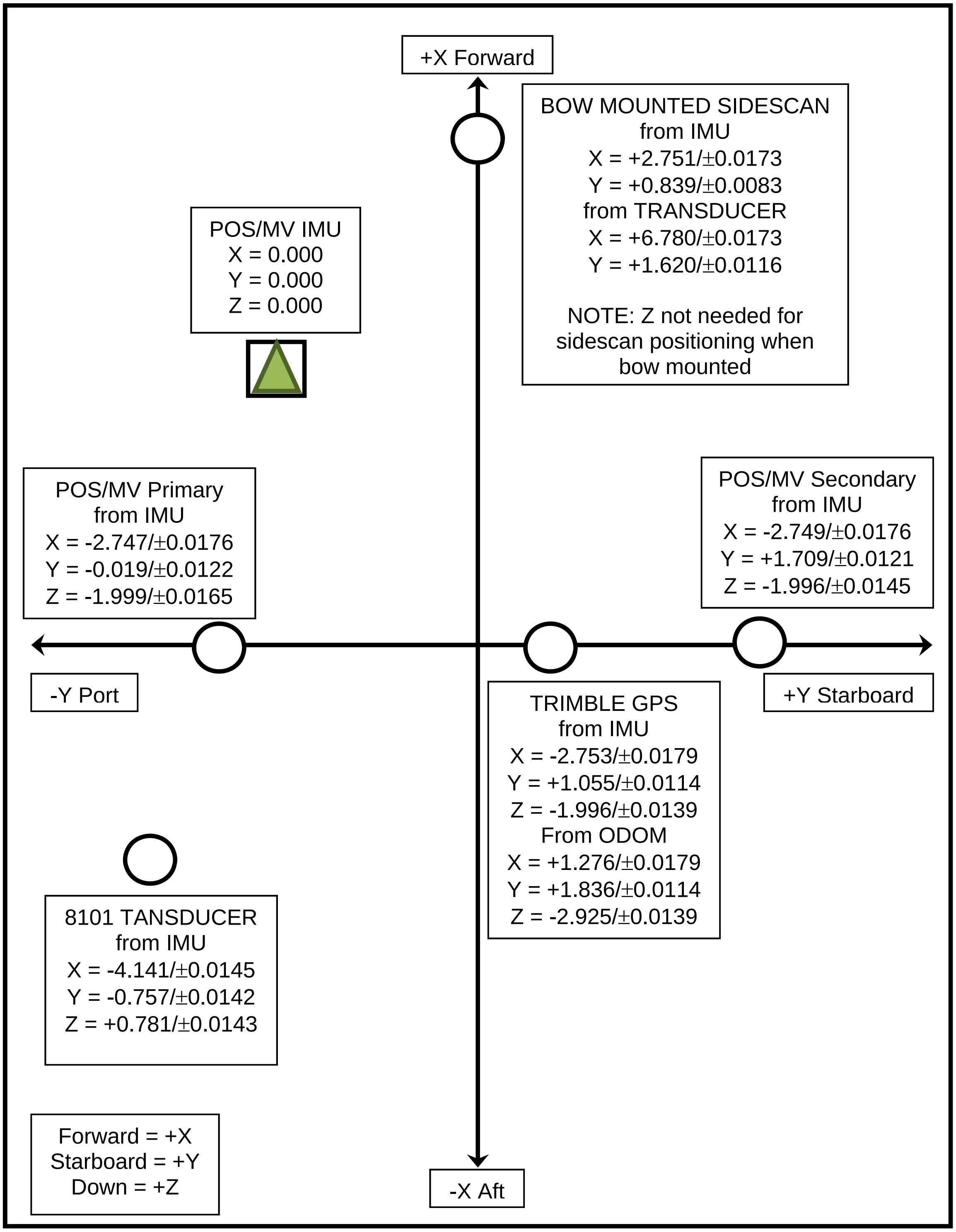

Figure C-4. 2013 Configuration and Offsets of *R/V Oyster Bay* Sensors for the RESON 8101 ER (measurements in meters with 1-sigma uncertainty)

Table C-4. 2013 / 2014 *R/V Oyster Bay* Antenna and RESON 8101 ER Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point (measurements in meters with 1-sigma uncertainty)

Sensor	Offset in ISS-2000		Offset in POS/MV	
Reson 8101Transducer Side Mount (Reference to Vessel Lever Arm)			X	-4.141±0.0145
			Y	-0.757±0.0142
			Z	+0.781±0.0143
Reference to Center of Rotation Lever Arm			X	-1.663±0.0100
			Y	+0.839±0.0081
			Z	0.000±0.0100
Reference to Sensor 1Lever Arm			X	-4.141±0.0145
			Y	-0.757±0.0142
			Z	+0.781±0.0143
POS/MV GPS Master Antenna (Reference to Primary GPS Lever Arm)			X	-2.747±0.0176
			Y	-0.019±0.0122
			Z	-1.999±0.0165
Trimble GPS Antenna From Transducer	X	+1.276±0.0179		
	Y	+1.836±0.0114		
	Z	-2.925 ±0.0139		
Bow Mounted Side scan (X and Y from Transducer. Z not needed for positioning bow mounted side scan)	X	+6.780±0.0173		
	Y	+1.620±0.0116		
	Z	N/A		

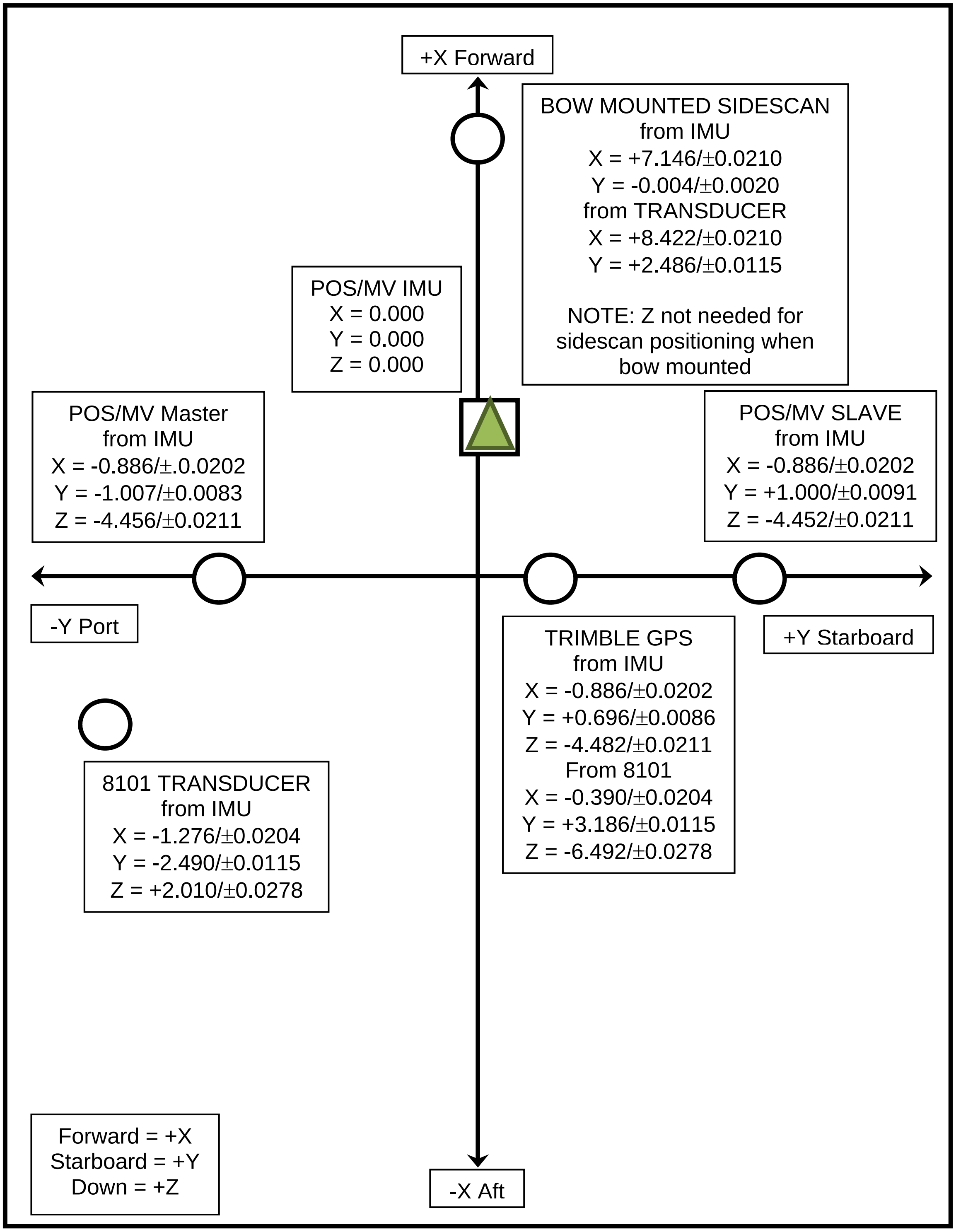

Figure C-5. 2013 Configuration and Offsets of *R/V Henry Hudson* Sensors for the RESON 8101 ER (measurements in meters with 1-sigma uncertainty)

Table C-5. 2013 *R/V Henry Hudson* Antenna and RESON 8101 ER Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point (measurements in meters with 1-sigma uncertainty)

Sensor	Offset in ISS-2000		Offset in POS/MV	
RESON 8101 Transducer Side Mount (Reference to Vessel Lever Arm)			X	-1.276 ±0.0204
			Y	-2.490 ±0.0115
			Z	+2.010 ±0.0278
Reference to Center of Rotation Lever Arm			X	-0.320 ±0.0104
			Y	+0.004 ±0.0020
			Z	0.000±0.002
Reference to Sensor 1Lever Arm			X	-1.276 ±0.0204
			Y	-2.490 ±0.0115
			Z	+2.010 ±0.0278
POS/MV GPS Master Antenna (Reference to Primary GPS Lever Arm)			X	-0.886 ±0.0202
			Y	-1.007 ±0.0083
			Z	-4.456 ±0.0211
Trimble GPS Antenna From Transducer	X	-0.390 ±0.0204		
	Y	+3.186 ±0.0115		
	Z	-6.492 ±0.0278		
A-Frame Tow Block (X and Y from RESON 8101 Transducer. Z is height above water.)	X	+8.422 ±0.0210		
	Y	+2.486 ±0.0115		
	Z	N/A		

C.1 Static and Dynamic Draft Measurements

C.1.1 Static Draft

Figure C-6 shows the 2013 draft determination for the *M/V Atlantic Surveyor*. The RESON 7125 SV transducer was hull-mounted approximately 3.50 meters below the vessel's main deck. To determine the draft, a 0.02 meter square metal bar was placed on the deck so that it extended out far enough to allow a direct measurement to the water line. The distance from the top of the metal bar to the water surface was measured and subtracted from the transducer hull depth to determine the draft of the transducer's acoustic center.

Static draft measurements were taken on each side of the vessel at each port call; both before departure and after arrival, in order to prorate the daily draft accounting for fuel and water consumption (see Section C.1.1.1). The two draft measurements (port and starboard) and the resulting draft value were recorded in the acquisition Navigation Log as well as in a separate vessel Draft Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed and prorated static draft for each survey is included with the survey data in Section I of the Separates of the DR for each sheet.

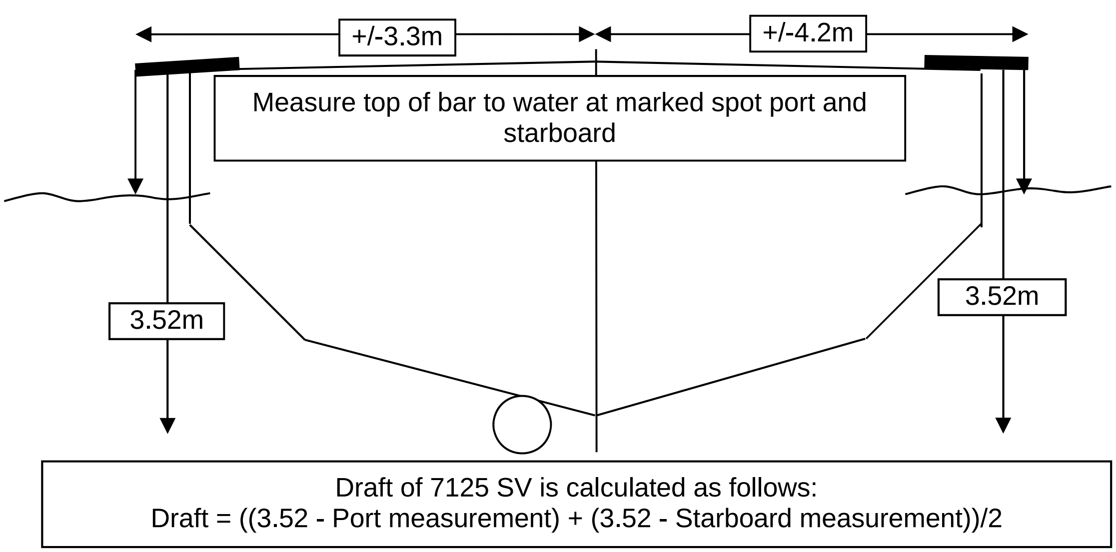

Figure C-6. 2013 *M/V Atlantic Surveyor* 7125 SV Draft Determination

Figure C-7 shows the 2013 draft determination for the *R/V Oyster Bay*. The ODOM CVM transducer was pole-mounted approximately 1.33 meters below the vessel's port side deck. To determine the draft, a reference point was established on the transducer pole-mount, approximately even with the port side deck, which allowed a direct measurement to the water line. The distance from the reference point to the water surface was measured and subtracted from the transducer depth to determine the draft of the transducer's acoustic center.

Static draft measurements were taken daily, both before departure and after arrival. The daily draft measurements and each resulting draft value were recorded in the acquisition Navigation Log as well as in a separate vessel Draft Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed static draft for each survey is included with the survey data in Section I of the Separates of the DR for each sheet.

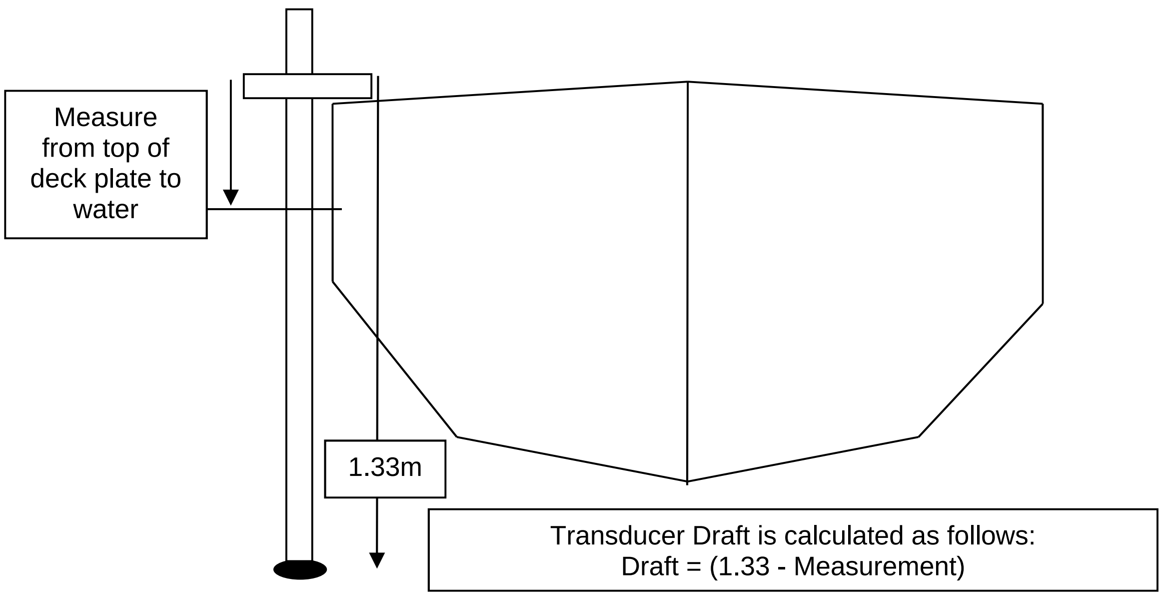

Figure C-7. 2013 *R/V Oyster Bay* Odom CVM Draft Determination

Figure C-8 shows the 2013 / 2014 draft determination for the *R/V Oyster Bay*. The RESON 8101 ER transducer was pole-mounted approximately 1.31 meters below the vessel's port side deck. To determine the draft, a reference point was established on the transducer pole-mount, approximately even with the port side deck, which allowed a direct measurement to the water line. The distance from the reference point to the water surface was measured and subtracted from the transducer depth to determine the draft of the transducer's acoustic center.

Static draft measurements were taken daily, both before departure and after arrival. The daily draft measurements and each resulting draft value were recorded in the acquisition Navigation Log as well as in a separate vessel Draft Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed static draft for each survey is included with the survey data in Section I of the Separates of the DR for each sheet.

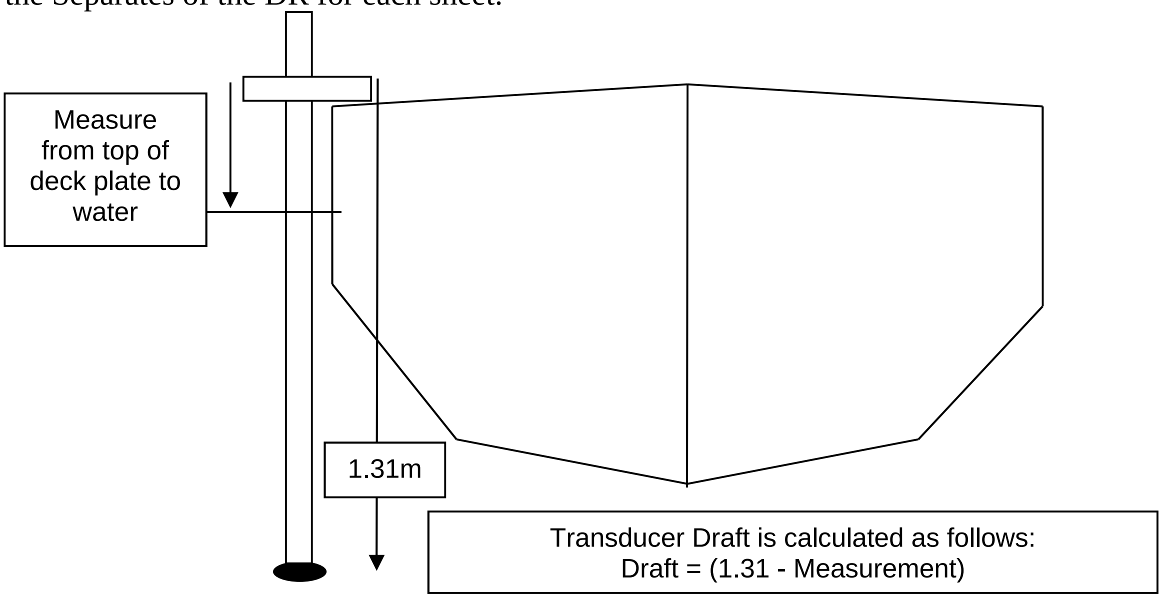

Figure C-8. 2013 / 2014 *R/V Oyster Bay* RESON 8101 ER Draft Determination

Figure C-9 shows the 2013 draft determination for the *R/V Henry Hudson*. The RESON 8101 ER transducer was pole-mounted approximately 3.01 meters below the vessel's port side deck. To determine the draft, a reference point was established on the transducer pole-mount, approximately even with the port side deck, which allowed a direct measurement to the water line. The distance from the reference point to the water surface was measured and subtracted from the transducer depth to determine the draft of the transducer's acoustic center.

Static draft measurements were taken daily, both before departure and after arrival. The daily draft measurements and each resulting draft value were recorded in the acquisition Navigation Log as well as in a separate vessel Draft Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed static draft for each survey is included with the survey data in Section I of the Separates of the DR for each sheet.

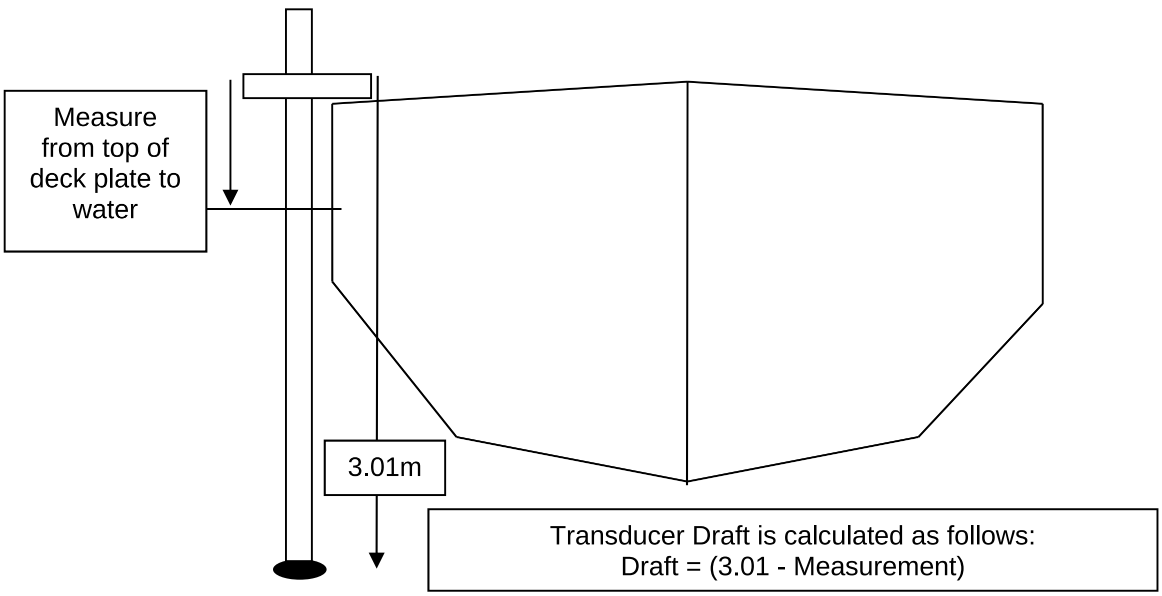

Figure C-9. 2013 *R/V Henry Hudson* RESON 8101 ER Draft Determination

C.1.1.1 Prorated Static Draft

An initial processing step of the Leidos data processing pipeline is to apply, if necessary, prorated static draft values to all bathymetric data. This was done to account for the change in the survey vessel draft during consecutive survey days, primarily due to fuel and water consumption. For these survey operations, the Leidos only implemented the prorated static draft procedure for multibeam data collected by the *M/V Atlantic Surveyor*.

As mentioned in Section C.1.1, the static draft was measured and recorded both prior to departure for the survey site, and immediately upon arrival to port after each survey leg. These two observed static draft measurements for each survey leg were then used to calculate the amount of change in the vessel static draft (in meters) observed over that survey leg. For a given period of survey, the change in vessel static draft divided by the number of consecutive days of survey resulted in the amount of change in vessel static draft per day. This daily change in the static draft was then subtracted from the observed static draft value at the beginning of that specific period of survey. This resulted in a unique prorated static draft value for each consecutive survey day that was then applied to the data for that day. When the JD rollover occurs in the middle of a survey line, the first file of the new day will be given the same prorated draft as the previous day. This procedure ensures that the static draft for every survey line is constant and does not cause a vertical jump in the survey depths.

This method was only used when continuous survey operations were conducted between the static draft measurements observed immediately prior to departure and immediately upon arrival to port. It assumed a constant amount of fuel and onboard water was consumed per day of continuous survey operations, thereby providing the ability to calculate a constant rate of change in the survey vessel draft per day.

The **Apply Correctors Offsets** tool within **SABER** was then used to apply the calculated prorated draft value for a given JD to all data within the multibeam GSF files of that specific JD. This process of applying a new prorated draft offset to the multibeam data was captured within the history record of each multibeam GSF file.

Once prorated static draft had been applied to the multibeam data for a JD, the **Apply Correctors Offsets** tool within **SABER** was then used to report all the current offsets applied to the data within the multibeam GSF files of that JD. This was done to ensure the expected prorated static draft value was correctly applied to all multibeam data for that day. In addition, the history record of the multibeam GSF files was reviewed to ensure the process of applying prorated draft was captured and done correctly.

The observed and prorated static draft for each survey is included with the survey data in Section I of the Separates of each sheet's Descriptive Report. The static draft applied to each individual GSF file is reported in the Multibeam or Singlebeam Processing Log for each sheet.

C.1.2 Dynamic Draft

Dynamic draft values were confirmed during the sea acceptance tests (SAT) performed for each survey vessel (see Appendix I for details).

For the *M/V Atlantic Surveyor* Table C-6 summarizes the shaft RPM, depth corrector, approximate speed, and the 2013 SAT multibeam files used to confirm the dynamic draft values (JD 191). The values determined from the analysis were entered into a look up table within the **ISS-2000** system. A shaft RPM counter provided automatic input to the **ISS-2000** system, which in conjunction with the look up table, applied a continuously updated dynamic settlement and squat value as data were collected.

Table C-6. 2013 *M/V Atlantic Surveyor* Settlement and Squat Confirmation

RPM	MB FILES (JD191)	SQUAT CORRECTOR USED	DELTA FROM DIFFERENCE GRIDS	1-SIGMA
0	asmba13191.d16	0.00	NA	NA
140	asmba13191.d18 asmba13191.d19	0.00	-0.019	0.021832
180	asmba13191.d20 asmba13191.d21	0.02	-0.018	0.027724
250	asmba13191.d22 asmba13191.d23	0.03	0.014	0.024766
300	asmba13191.d24 asmba13191.d25	0.06	-0.010	0.024220
340	asmba13191.d27 asmba13191.d28	0.09	-0.013	0.025431
380	asmba13191.d29 asmba13191.d30	0.11	-0.016	0.027253
AVERAGE STANDARD DEVIATION				0.025204

For the *R/V Oyster Bay* Table C-7 summarizes the engine RPM, depth corrector, approximate speed, and the singlebeam and multibeam files used to determine dynamic draft values (JD 231) and to confirm the dynamic draft values (JD 239 and JD 325). The values determined from the analysis were entered into a look up table within the **ISS-2000** system. An engine RPM counter with digital display provided RPM values to the vessel captain and the hydrographer. The RPM value in use was then manually input into the **ISS-2000** system, which in conjunction with the look up table, applied a continuously updated dynamic settlement and squat value as data were collected.

Table C-7. 2013 *R/V Oyster Bay* Settlement and Squat Confirmation

Engine RPM	Depth Corrector	Approximate Speed (Kts)	1-Sigma	SB Files (JD231) Determination	SB Files (JD239) Confirmation	MB Files (JD325) Confirmation
0	0.00	0	0.00000	OBSBH13231.D01 OBSBH13231.D13	N/A	OBMBA13325.D42
600	0.04	2.5	0.022730	OBSBH13231.D02 OBSBH13231.D14	OBSBH13239.D02	OBMBA13325.D43 OBMBA13325.D44
1600	0.04	6.5	0.034372	OBSBH13231.D07 OBSBH13231.D17	OBSBH13239.D03 OBSBH13239.D04	OBMBA13325.D49 OBMBA13325.D50
2000	0.00	8	0.041895	OBSBH13231.D09 OBSBH13231.D18	OBSBH13239.D05	OBMBA13325.D50 OBMBA13325.D51
2400	-0.05	9.5	0.022418	OBSBH13231.D12 OBSBH13231.D20	OBSBH13239.D06	OBMBA13325.D51 OBMBA13325.D52

For the *R/V Henry Hudson* Table C-8 summarizes the engine RPM, depth corrector, approximate speed, and the multibeam files used to determine dynamic draft values (JD 235 and JD 237) and to confirm the dynamic draft values (JD 239). The values determined from the analysis were entered into a look up table within the **ISS-2000** system. An engine RPM counter with digital display provided RPM values to the vessel captain and the hydrographer. The RPM value in use was then manually input into the **ISS-2000** system, which in conjunction with the look up table, applied a continuously updated dynamic settlement and squat value as data were collected.

Table C-8. 2013 *R/V Henry Hudson* Settlement and Squat Confirmation

Engine RPM	Depth Corrector	Approximate Speed (Kts)	1-Sigma	MB Files (JD235) Determination	MB Files (JD237) Determination	MB Files (JD239) Confirmation
0	0.00	0.0	0.000000	HHMBA13235.D31	N/A	HHMBA13239.D27
400	0.00	3.5	0.017078	HHMBA13235.D32 HHMBA13235.D33 HHMBA13235.D34 HHMBA13235.D35	HHMBA13237.D05 HHMBA13237.D06	HHMBA13239.D17 HHMBA13239.D18
800	0.00	5.0	0.015588	HHMBA13235.D37 HHMBA13235.D38 HHMBA13235.D39 HHMBA13235.D40	HHMBA13237.D07 HHMBA13237.D08	HHMBA13239.D19 HHMBA13239.D20
1000	0.02	6.0	0.015946	HHMBA13235.D41 HHMBA13235.D42 HHMBA13235.D43	HHMBA13237.D09 HHMBA13237.D10	HHMBA13239.D21 HHMBA13239.D22
1300	0.04	7.5	0.014339	HHMBA13235.D44 HHMBA13235.D45 HHMBA13235.D46 HHMBA13235.D47	HHMBA13237.D11 HHMBA13237.D12	HHMBA13239.D23 HHMBA13239.D24
1600	0.06	8.8	0.014655	HHMBA13235.D48 HHMBA13235.D50 HHMBA13235.D51 HHMBA13235.D52	HHMBA13237.D13 HHMBA13237.D14	HHMBA13239.D25 HHMBA13239.D26

C.1.3 Speed of Sound

A Moving Vessel Profiler (MVP), manufactured by Brooke Ocean Technology Ltd., with an Applied Microsystems Ltd. Smart Sound Velocity and Pressure (SV&P) sensor, as well separate Seabird Electronics SBE-19 CTD sensors were used to determine sound speed profiles for corrections to multibeam sonar soundings.

Confidence checks were obtained periodically (every 6-13 days) two consecutive casts taken with different SV&P sensors, with a SV&P sensor and a Seabird SBE-19 CTD, or between two different Seabird SBE-19 CTDs. After downloading the sound speed profile (SSP) comparison casts, graphs and tabulated lists were used to compare the two casts.

During multibeam and singlebeam acquisition, SSP casts were uploaded to **ISS-2000** immediately after they were taken. In **ISS-2000**, the profiles were reviewed for quality, edited as necessary, compared to the preceding casts, and then applied (loaded into the multibeam or singlebeam system for use).

Once applied, the multibeam system used the profile data for depth calculation and ray tracing corrections to the multibeam data. If sounding depths exceeded the cast depth, the **ISS-2000** used the deepest sound speed value of the profile to extend the profile to the maximum depth.

Factors considered in determining how often a SSP cast was needed included shape and proximity of the coastline, sources and proximity of freshwater, seasonal changes, wind, sea state, water depth, observed changes from the previous profiles, and differences in the surface sound speed of the current profile compared to a separate surface sound speed sensor collocated with the multibeam sonar. At a minimum, for survey operations on the *M/V Atlantic Surveyor* SSP casts were taken at the beginning of each survey leg, at approximately two-hour intervals, and at the end of each survey leg. During daily survey operations for the *R/V Oyster Bay* and *R/V Henry Hudson*, SSP casts were taken, at a minimum, before the start of bathymetric data acquisition, midway through the survey day, and at the end of bathymetric data collection for each survey day.

Quality control tools in **ISS-2000**, including real-time displays of color-coded coverage and a multibeam swath waterfall display, were used to monitor how the sound speed affected the multibeam data. By using these techniques any severe effects due to sound speed profiling could be seen when viewing multibeam data in an along-track direction. Proper sound speed application and effects were also analyzed throughout the survey during post processing using the Leidos **Analyze Crossings** software and by PFM review of final uncertainties.

A Sound Speed Profile Log including details of all SSP casts (such as date, location, application times, and maximum depth) is located in Separates II of the DR for each sheet. These Logs are separated by the purpose of the applied cast, categorizing each SSP file as "Used_for_Bathymetry" (applied to online bathymetry data), "Used_for_Closing" (a separate cast applied at the end of a survey leg immediately after online data collection needed for TPU calculations), "Used_for_Comparison", and "Used_for_Lead_Line".

Additionally, in a separate folder on the delivery drive, in the "HXXXXX/Data/Processed/SVP/CARIS_SSP" folder, there are eight sound speed profile files (.svp). These eight files contain concatenated SSP data that has been formatted for use in CARIS. The CARIS SSP files are designated based on the type of sensor and the purpose of the cast and their filenames match the tabs within the sound speed profile log.

C.2 MULTIBEAM CALIBRATIONS

A Sea Acceptance Test (SAT) was conducted independently for each survey vessel and sonar installation, prior to the start of each vessel's multibeam or singlebeam data acquisition for sheets H12586 and H12587. Additional SAT tests were performed each time an acquisition system installation was reinstalled or changed.

The SAT for the *M/V Atlantic Surveyor* integrated with the RESON 7125 SV multibeam system was conducted from 08 July 2013 (JD189) through 12 July 2013 (JD193).

An initial SAT for the *R/V Oyster Bay* was conducted from 16 August 2013 (JD228) to 19 August 2013 (JD231) while the system onboard was integrated with the ODOM CVM singlebeam sonar. Additional SAT tests were conducted from 27 August 2013 (JD239) to 31 August 2013 (JD243) to verify the ODOM CVM reinstallation after the transducer had struck a submerged wreck on 25 August 2013 (JD237) which resulted in removal and repair of the singlebeam transducer mount.

On 20 November 2013 the ODOM CVM singlebeam was replaced by the RESON 8101 ER multibeam system onboard the *R/V Oyster Bay*. A SAT of the *R/V Oyster Bay* with the RESON 8101 ER integrated onboard was then conducted from 20 November 2013 to 22 November 2013.

The SAT for the *R/V Henry Hudson* integrated with the RESON 8101 ER multibeam system was conducted from 21 August 2013 (JD233) to 23 August 2013(JD235). On 02 October 2013 (JD275) the RESON 8101 ER transducer struck a large uncharted rock which separated the mounting brace, for the multibeam transducer pole, off from the hull of the vessel. The result of which required the multibeam transducer to be raised out of the water for inspection and for necessary repairs to be made to the multibeam transducer pole's mounting brace. Upon completion of the necessary repairs, the RESON 8101 ER transducer was redeployed on 03 October 2013 (JD276) and a SAT of the systems then began. While these SAT operations were still ongoing, the vessel drifted over a shoal, causing the mounting brace for the multibeam transducer pole to separate from the vessels hull again on 05 October 2013 (JD278). Additional repairs were made to the mounting brace, the RESON 8101 ER was redeployed to survey position, and SAT tests resumed on 06 October 2013 (JD279) which continued through 08 October 2013 (JD281).

Navigation positioning, heading, heave, roll, and pitch were provided by the Applanix POS/MV 320 Inertial Navigation System. Resolution and accuracy of this system are:

- Heave Resolution 1 cm, Accuracy greater of 5 cm or 5% of heave amplitude
- Roll Resolution 0.01º, Accuracy 0.02º
- Pitch Resolution 0.01º, Accuracy 0.02º

The Applanix *TrueHeave*™ option was used to record delayed heave for application in post processing (see Section C.3 for details of delayed heave and the application process).

C.2.1 Timing Test

A ping timing test for the RESON 7125 SV was completed on 09 July 2013 (JD190) to verify that no timing errors existed within the survey system (see Appendix II). The fundamental tool was the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going transistor-transistor logic (TTL) pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest were the transmit trigger of the RESON 7-P and the 1PPS timing pulses from the POS/MV. These tests demonstrated that all GSF ping times matched the corresponding IRIG-B event times to within 1.5 milliseconds (Figure C-10).

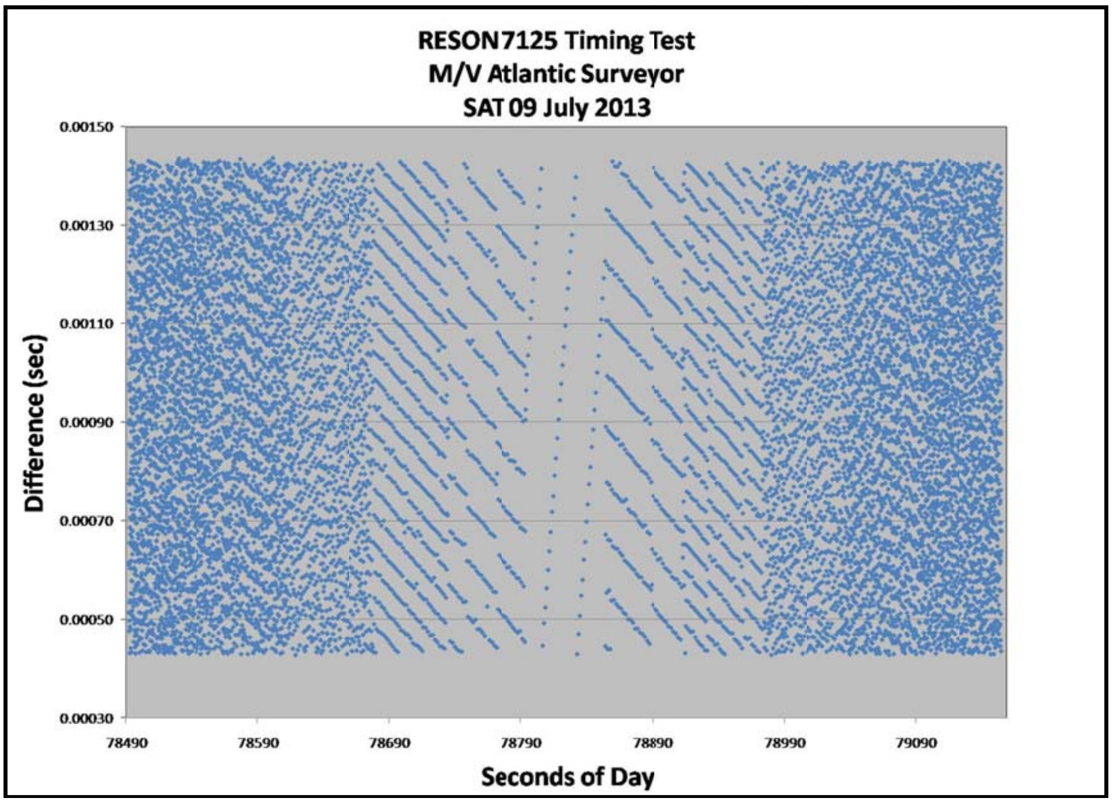

Figure C-10. 09 July 2013 RESON 7125 SV Timing Test Results (time differences of ping trigger event vs. ping time tag from GSF)

A ping timing test for the ODOM CVM was completed on 12 August 2013 (JD224) to verify that no timing errors existed within the survey system (see Appendix II). The fundamental tool was the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going transistor-transistor logic (TTL) pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest were the transmit trigger of the ODOM CVM and the 1PPS timing pulses from the POS/MV. These tests demonstrated that all GSF ping times matched the corresponding IRIG-B event times to within 1.5 milliseconds (Figure C-11).

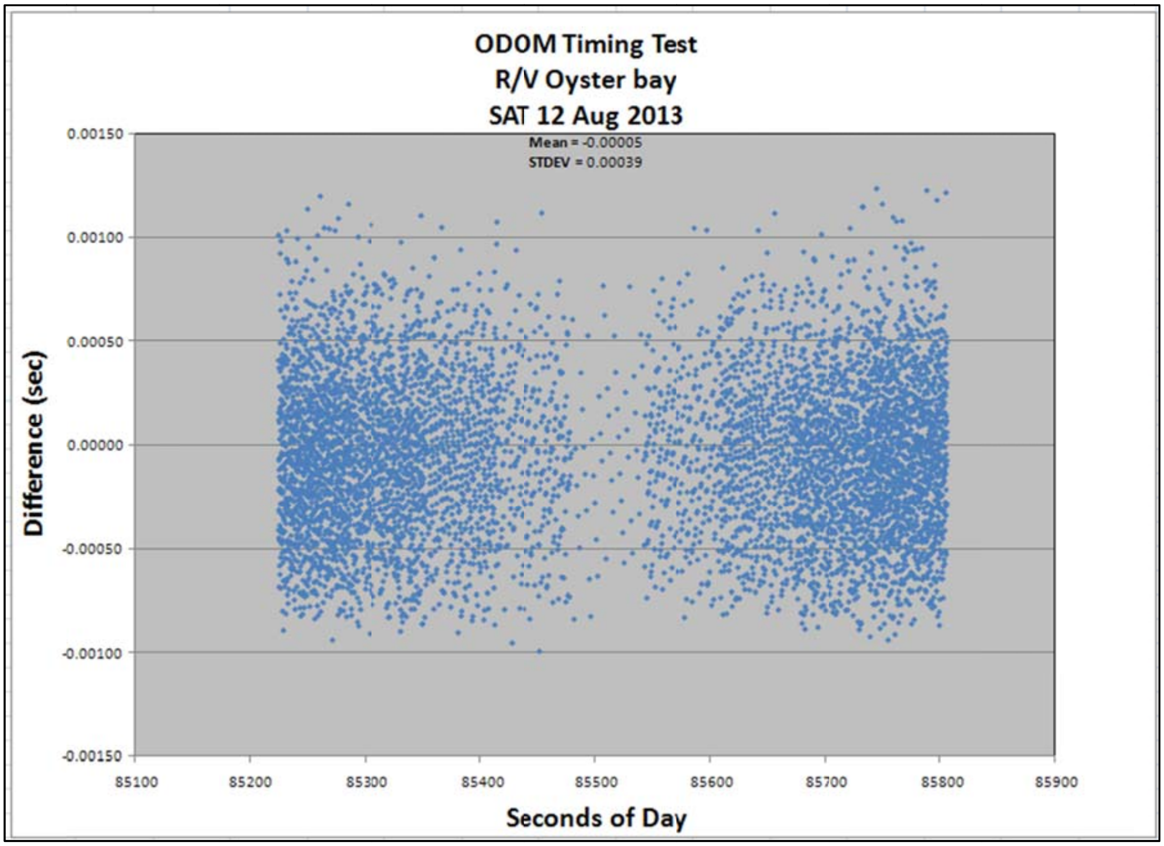

Figure C-11. 12 August 2013 ODOM CVM Timing Test Results (time differences of ping trigger event vs. ping time tag from GSF)

A ping timing test for the RESON 8101 ER installed onboard the *R/V Henry Hudson* was completed on 22 August 2013 (JD234) to verify that no timing errors existed within the survey system (see Appendix II). The fundamental tool was the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going transistor-transistor logic (TTL) pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest were the transmit trigger of the RESON 8101 ER and the 1PPS timing pulses from the POS/MV. These tests demonstrated that the average of all GSF ping times matched the corresponding IRIG-B event times to within 1.5 milliseconds (Figure C-12).

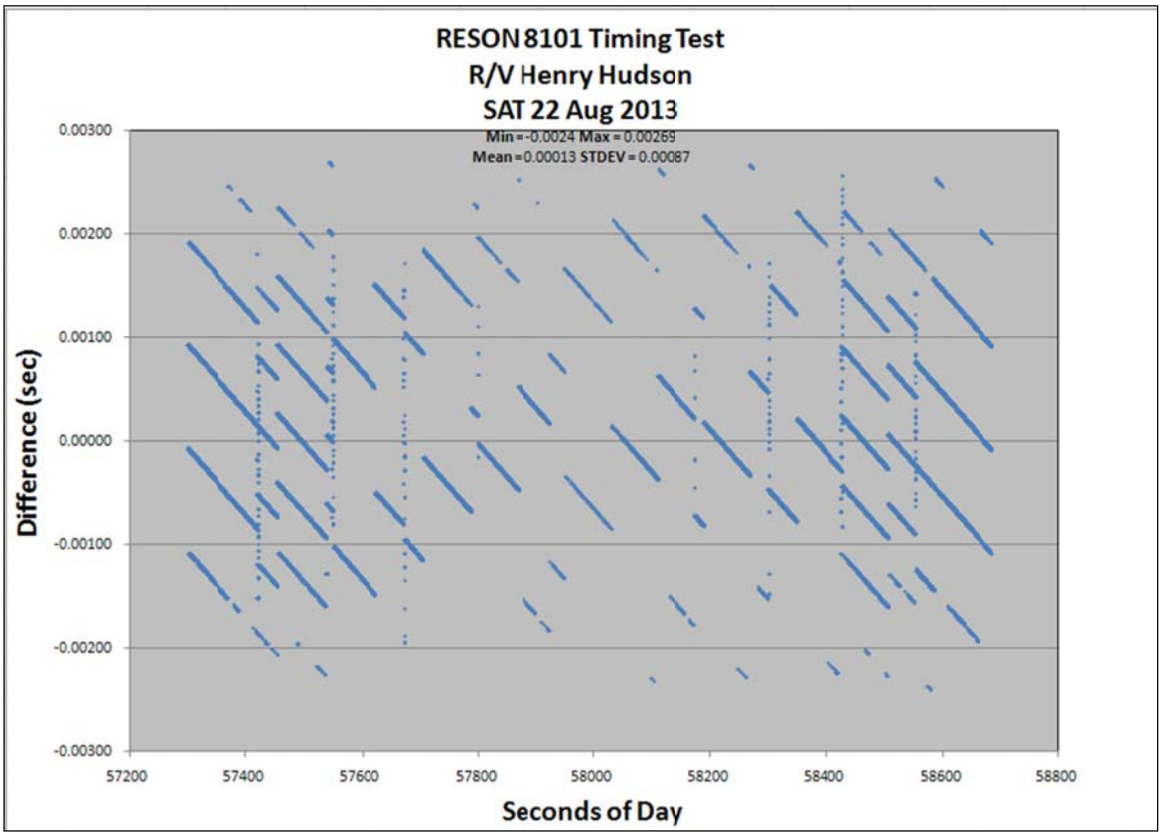

Figure C-12. 22 August 2013 RESON 8101 ER Timing Test Results for the *R/V Henry Hudson* (time differences of ping trigger event vs. ping time tag from GSF)

A ping timing test for the RESON 8101 ER installed onboard the *R/V Oyster Bay* was completed on 21 November 2013 (JD325) to verify that no timing errors existed within the survey system (see Appendix II). The fundamental tool was the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going transistor-transistor logic (TTL) pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest were the transmit trigger of the RESON 8101 ER and the 1PPS timing pulses from the POS/MV. These tests demonstrated that the average of all GSF ping times matched the corresponding IRIG-B event times to within 1.5 milliseconds (Figure C-13).

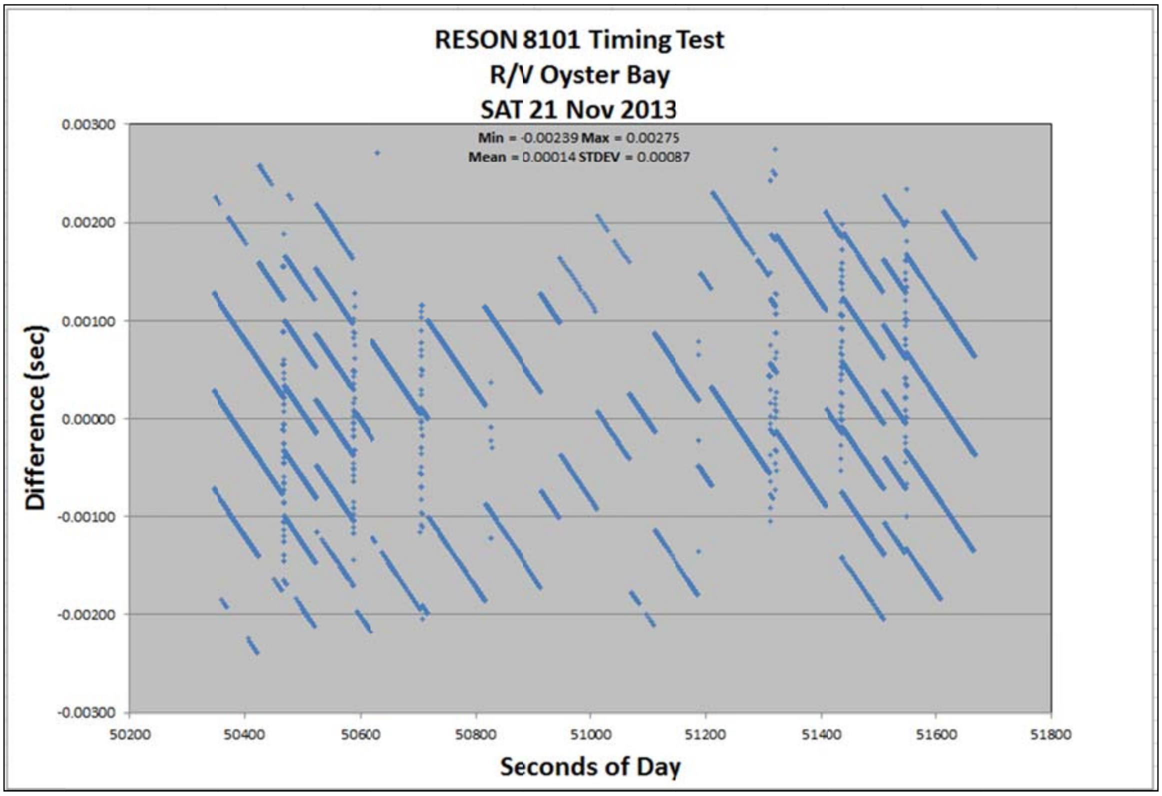

Figure C-13. 21 November 2013 RESON 8101 ER Timing Test Results for the *R/V Oyster Bay* (time differences of ping trigger event vs. ping time tag from GSF)

C.2.2 Multibeam Bias Calibration (Alignment)

Roll, pitch, and heading biases were determined on 10 July 2013 (JD191) for the RESON 7125 SV installed on the *M/V Atlantic Surveyor* (see Appendix II for details). The results are presented in Table C-9.

Table C-9. Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 10 July 2013 RESON 7125 SV on the *M/V Atlantic Surveyor*

Component	Multibeam Files		Result
Pitch	asmba13191.d44	asmba13191.d45	+1.240°
Roll	asmba13191.d47	asmba13191.d48	+0.340°
Heading	asmba13191.d52	asmba13191.d53	+0.300°

Roll, pitch, and heading biases were determined on 23 August 2013 (JD235) for the RESON 8101 ER installed on the *R/V Henry Hudson* (see Appendix II for details). The results are presented in Table C-10.

Table C-10. Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 23 August 2013 RESON 8101 ER on the *R/V Henry Hudson*

Component	Multibeam Files		Result
Pitch	hhmba13235.d16	hhmba13235.d17	+0.060°
Roll	hhmba13235.d58	hhmba13235.d59	+0.948°
Heading	hhmba13235.d21	hhmba13235.d26	+2.100°

Roll, pitch, and heading biases were re-determined on 08 October 2013 (JD281) for the RESON 8101 ER on the *R/V Henry Hudson*, following the repair of the mounting brace for the transducer pole (see Appendix II for details). The results are presented in Table C-11.

Table C-11. Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 08 October 2013 RESON 8101 ER on the *R/V Henry Hudson*

Component	Multibeam Files		Result
Pitch	hhmba13281.d17	hhmba13281.d18	-7.000°
Roll	hhmba13281.d27	hhmba13281.d28	+0.000°
Heading	hhmba13281.d13	hhmba13281.d14	+1.800°

Roll, pitch, and heading biases were determined on 22 November 2013 (JD326) for the RESON 8101 ER installed on the *R/V Oyster Bay* (see Appendix II for details). The results are presented in Table C-12.

Table C-12. Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 22 November 2013 RESON 8101 ER on the *R/V Oyster Bay*

Component	Multibeam Files		Result
Pitch	obmba13326.d32	obmba13326.d33	+0.660°
Roll	obmba13326.d34	obmba13326.d35	-1.255°
Heading	obmba13326.d39	obmba13326.d40	-0.100°

C.2.3 Multibeam Accuracy

During the July 2013 SAT of the *M/V Atlantic Surveyor,* a survey was run to analyze multibeam accuracies with the RESON 7125 SV (see Appendix II for details). The survey was run in the vicinity of a 47 foot wreck in the fish haven approximately 6 kilometers southeast of Manasquan Inlet. The wreck is located in 40° 03.3925'N 073° 59.5541'W. All depths were corrected for predicted tides and zoning using the Atlantic City tide gage, 8534720. The class 1 cutoff angle was set to 5° and the class 2 cutoff angle was set to 60°. The multibeam was configured for 256 Equi-Angular beams. Standard multibeam data processing procedures were followed to clean the data, apply delayed heave, and calculate errors. One-meter minimum grids of main scheme lines, class 1 crosslines, and all lines were created and analyzed.

A two-meter PFM of all the data was also generated and the **Gapchecker** and **Check Uncertainty** routines were run on the PFM CUBE depth layer. Multibeam features, side scan contacts, and selected soundings in feet were generated.

The results showed that the system met the uncertainty standards stated in Section 5.1.3 of the HSSD.

On 01 September 2013 (JD244), after the completion of the individual SAT testing for all three survey vessels, a confidence check of the multibeam systems was made by comparing the depth data collected over a common survey line which was run simultaneously by the *R/V Oyster Bay,* the *R/V Henry Hudson*, and the *M/V Atlantic Surveyor*. For this comparison of the multibeam systems and singlebeam system, the three vessels met, took and applied individual SSP casts, and then proceeded to acquire data over a common survey line, one vessel immediately following the other to reduce any tidal or environmental differences.

The data acquired over this common survey line were fully processed following standard bathymetric data processing procedures to clean the data, apply delayed heave, and calculate errors. Separate one-meter minimum grids of the data from each vessel as well as individual two-meter PFM grids of the data from each were generated and analyzed. The **Check PFM Uncertainty** routine was run on each of the individual PFM CUBE Depth layers. Difference grids were generated between the individual PFM CUBE Depth layers and the **SABER Junction Analysis** routine (Section B.2.2) was run and the results of the **SABER Frequency Distribution** tool were analyzed.

All results showed that the systems met the accuracy and uncertainty standards stated in Section 5.1.3 of the HSSD.

Additional comparisons between multiple survey vessels were performed periodically during the survey throughout the timeframe that two or more survey vessels were in operation.

C.3 DELAYED HEAVE

As discussed in Section B.2, Leidos and **SABER** use the terminology delayed heave to describe Applanix *TrueHeave*™ data collected from the Applanix POS/MV.

At the start of all survey operations, the Applanix POS/MV was configured to log *TrueHeave*™ data. The delayed heave files (.thv) were recorded using **ISS-2000** and archived to the NAS or external hard drive in the same manner as GSF files. The delayed heave data were calculated by the Applanix POS/MV based on an algorithm which used a range of temporally bounding Applanix POS/MV real-time heave data to produce a more accurate value of heave. When the resulting delayed heave values were applied to the multibeam data they reduced heave artifacts present from variables such as sea state and survey vessel maneuvering, which are commonly observed in multibeam data with only real-time heave applied.

When delayed heave corrections were applied to the bathymetric data, each depth value was fully recalculated in **SABER**. This was possible because the raw beam angle and travel time values were recorded in the GSF file. The raw beam angle and travel time values were used along with the vessel attitude (including heave) and re-ray traced. As delayed heave was applied, a history record was written to each GSF file, and the ping flag of each modified ping was updated.

After the application of delayed heave was complete, all bathymetric data were reviewed to verify that the delayed heave values were applied using the **SABER** command line program **check_heave**. This program read through the ping flags of each GSF record to check the application of delayed heave. When the **check_heave** program found instances where delayed heave was not applied, it output report files which included the GSF filename, as well as the time range for the gap in delayed heave application. The data from the **check_heave** reports was then used to further investigate all instances of gaps in delayed heave application.

Leidos strived to have delayed heave applied to all soundings of multibeam data, however there were times when this was not possible. Real-time heave was used in place of delayed heave in all instances where there were gaps in the application of delayed heave. All gaps in delayed heave application were fully investigated and the data reviewed to verify that the real-time heave values were appropriate to the surrounding available delayed heave values. Any instances where the absence of delayed heave adversely affected the data will be discussed in the DR for the respective sheet.

C.4 TIDES AND WATER LEVELS

NOAA tide station 8531680 Sandy Hook, NJ was specified in the OPR-D302-KR1-13 Project Instructions to be used as the source for water level correctors for these surveys. Leidos also received a Statement of Work (03/13/2013 CU) which provided further details about the water level correctors including zoning information. Leidos received the zoning information in a CARIS Zone Definition File format (.zdf) and MapInfo data files. Leidos used **SABER Survey Planning** to create tide zone files (.zne) based on the positional data provided from the *.zdf files, for use within **ISS-2000** and **SABER**.

All tide data for the project were downloaded from the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) Tides & Currents website. Predicted tide levels were used for real-time data acquisition and observed verified tides were later downloaded for the computation of the final water level correctors. All 6-minute water level data were in meters and annotated with the Coordinated Universal Time (UTC). Leidos downloads the predicted tide and verified data from the NOAA Center for Operational Oceanographic Products and Services Tides & Currents website as a text file (.txt).

The **SABER Create Water Level Files** tool was used to generate the final water level files for each tide zone. This tool generates a Tide Zone Parameters (.tzp) file and water level files. The Tide Zone Parameter file contains tide zone specifics for each of the zones within the survey area, such as time offset and range ratio. These values listed in Table C-4 were obtained from NOAA. Leidos did not modify any of these parameters. Once the *.tzp file is generated it is used to create water level files. These files were created based on the data input from the downloaded predicted or verified tide data that was saved as a text file. **SABER** outputs the water level files by zone with a file extension corresponding to the type of data (predicted or verified) were within the input text file. For example, SA46.ov is a water level file for Zone SA46 that includes verified water level data.

These water level files were applied to the multibeam data using the **SABER Apply Tides** program. This program took the water level heights contained within the water level files and algebraically subtracted them from surveyed depths to correct each sounding for tides.

When updated water level correctors (such as verified tides) were applied to the GSF files, the program removed the previous water level corrector and applied the new corrector. Each time the program was run on the GSF files, a history record was appended to the end of the GSF file documenting the date and water level files applied. For quality assurance, the **SABER Check Tide Corrections in GSF** program was run on all GSF files to confirm that the appropriate water level corrector had been applied to the final GSF files. The primary means for analyzing the adequacy of the correctors was observing zone boundary crossings in **SABER**'s **MultiView Editor**.

After confirmation that verified water levels were applied to all bathymetric data, grids were created and analyzed using various color change intervals and shaded relief. The color intervals and shaded relief provided a means to check for significant, unnatural changes in depth across zone boundaries due to water level correction errors, unusual currents, storm surges, etc.

In addition, crossline analysis using the **SABER Junction Analysis** routine was run and the results of the **SABER Frequency Distribution** tool were analyzed and used to identify possible depth discrepancies resulting from the applied water level correctors. Discrepancies were further analyzed to determine if they were the result of incorrect zoning parameters or weather (wind) conditions between the tide station and the survey area.

No final tide note was provided by the NOAA Center for Operational Oceanographic Products and Services (CO-OPS). Leidos is not required to have a final tide note from CO-OPS for OPR-D302-KR1-13.

Additionally, in a separate folder on the delivery drive for each sheet, in the "HXXXXX/Data/Processed/Tide/CARIS_Tide_Files" folder, are support files for use in CARIS. Leidos created each CARIS Tide File (*.tid) using the same observed verified water level data downloaded from the NOAA CO-OPS Tides & Currents website that is used for creating the observed verified water level data files (*.ov) used in **SABER**. Then the *.tid file was reformatted to meet the file structure used in CARIS. Also included in this directory is the Zone Definition File (B310KR12013CORP.zdf), which Leidos received with the Statement of Work (03/13/2013 CU).

C.4.1 Final Tide Note

All surveys were contained within preliminary water level zones NY1, NY3, NY7, NY8, NY9, SHB0, SHB1, SHB2, SHB3, SHB4, SHB5, SHB6, SHB7, SHB11, SHB13, SHB14, SHB15, and SHB16 (Figure C-14) which are referenced to NOAA tide station 8531680 Sandy Hook, NJ. The NOAA provided zoning parameters are presented in Table C-13 for tide station 8531680 Sandy Hook, NJ.

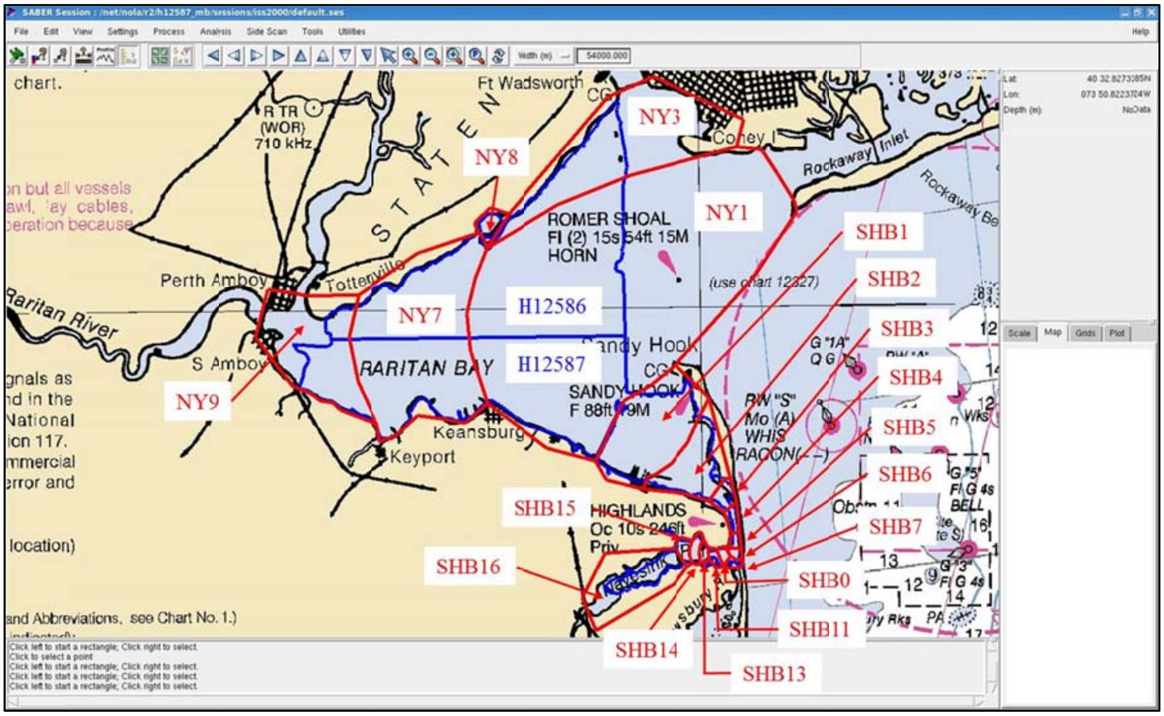

Figure C-14. Tide Zones for Station 8531680 Covering Survey Areas H12586 and H12587

Table C-13. Preliminary Tide Zone Parameters for 8531680 Sandy Hook, NJ

Zone	Time Corrector (minutes)	Range Ratio	Reference Station
NY1	-6	x1.01	8531680
NY3	+6	x1	8531680
NY7	0	x1.04	8531680
NY8	+12	x1.01	8531680
NY9	+6	x1.07	8531680
SHB0	+54	x0.8	8531680
SHB1	0	x0.99	8531680
SHB2	+6	x0.96	8531680
SHB3	+12	x0.93	8531680
SHB4	+18	x0.89	8531680
SHB5	+30	x0.85	8531680
SHB6	+42	x0.81	8531680
SHB7	+54	x0.78	8531680
SHB11	+60	x0.79	8531680
SHB13	+72	x0.77	8531680
SHB14	+78	x0.76	8531680
SHB15	+84	x0.73	8531680
SHB16	+96	x0.73	8531680

The verified water level correctors were computed at six minute intervals for each zone and referenced to the Mean Lower-Low Water (MLLW) vertical datum. Analysis of the bathymetric data in **MVE** and in depth grids revealed minimal depth jumps across the junction of the zones. A spreadsheet analysis of the water level correctors for each zone and the differences observed at the boundaries of adjacent zones also confirmed the adequacy of zoning correctors based on 8531680 Sandy Hook, NJ.

For the zone junction analysis, observed verified water levels from 01 August 2013 (JD213) through 26 January 2014 (JD026) were entered into the spreadsheet for reference. Differences were computed zone-to-zone and are summarized in Table C-14.

Table C-14. 2013-2014 Differences in Water Level Correctors between Adjacent Zones Using Zoning Parameters for Station 8531680

Zone Boundary	Minimum Difference	Maximum Difference	Average Difference	Standard Deviation
NY1-NY3	-0.347	0.282	0.009	0.054
NY1-SHB1	-0.303	0.326	0.018	0.030
NY1-NY7	-0.360	0.285	-0.026	0.033
NY1-NY8	-0.385	0.252	0.000	0.080
NY9-NY7	-0.294	0.369	0.026	0.034
NY7-NY8	-0.334	0.307	0.026	0.057
NY3-NY8	-0.333	0.299	-0.009	0.028
NY3-NY7	-0.352	0.289	-0.035	0.036
SHB1-SHB2	-0.284	0.329	0.026	0.032
SHB2-SHB3	-0.275	0.320	0.026	0.031
SHB3-SHB4	-0.254	0.319	0.035	0.033
SHB4-SHB5	-0.269	0.274	0.035	0.051
SHB5-SHB6	-0.255	0.264	0.035	0.050
SHB5-SHB0	-0.283	0.258	0.044	0.091
SHB6-SHB7	-0.252	0.245	0.026	0.046
SHB6-SHB0	-0.276	0.228	0.009	0.043
SHB7-SHB0	-0.047	0.012	-0.018	0.011
SHB0-SHB11	-0.246	0.254	0.009	0.023
SHB11-SHB13	-0.257	0.231	0.018	0.043
SHB13-SHB14	-0.237	0.245	0.009	0.022
SHB14-SHB15	-0.210	0.258	0.026	0.026
SHB15-SHB16	-0.259	0.198	0.000	0.039

As a result, the NOAA preliminary zone boundaries and zoning parameters for 8531680 Sandy Hook, NJ, were accepted as final and applied to all multibeam data.

D. APPROVAL SHEET

14 April 2014

LETTER OF APPROVAL

REGISTRY NUMBER: H12586 and H12587

Field operations and data processing contributing to the accomplishment of these surveys, H12586 and H12587, were conducted under my supervision and that of the other Leidos lead hydrographers with frequent personal checks of progress and adequacy. This report and accompanying deliverable data items have been closely reviewed and are considered complete and adequate as per the Statement of Work.

This report and the accompanying digital data for project OPR-B310-KR1-13, New York Harbor and Approaches, are respectfully submitted. All records are forwarded for final review and processing.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Specifications Deliverables Manual. These data are adequate to supersede charted data in their common areas.

Reports concurrently submitted to NOAA for this project include:

Report	Submission Date
H12586 Descriptive Report	14 April 2014

Gary R. Davis

Digitally signed by Gary R. Davis
DN: cn=Gary R. Davis, o=Marine Survey and Engineering Solutions, ou=Leidos, email=gary.r.davis@leidos.com, c=US
Date: 2014.04.14 01:10:25 -04'00'

Gary R. Davis
Chief Hydrographer
Leidos Corporation
14 April 2014