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Data Acquisition & Processing Report

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Time Frame: *24 September 2015 – 15 December 2015*

LOCALITY

State *Louisiana*

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2015

CHIEF OF PARTY

Paul L. Donaldson
Leidos

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Data Acquisition & Processing Report

OPR-K371-KR-15

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ACRONYMS

Acronym	Definition
ACD	Automatic Contact Detection
AHB	Atlantic Hydrographic Branch
ASCII	American Standard Code for Information Interchange
BAG	Bathymetric Attributed Grid
CI	Confidence Interval
CMG	Course Made Good
COR	Contracting Officer's Representative
CTD	Conductivity, Temperature, Depth profiler
CUBE	Combined Uncertainty and Bathymetric Estimator
DAPR	Data Acquisition and Processing Report
DGPS	Differential Global Positioning System
DPC	Data Processing Center
DR	Descriptive Report
ECDIS	Electronic Chart Display and Information System
EPF	Error Parameters File
FMGT	Fledermaus Geocoder Toolbox
Ft	Feet
GPS	Global Positioning System
GSF	Generic Sensor Format
HDCS	Hydrographic Data Cleaning System
HSSD	NOS Hydrographic Surveys Specifications and Deliverables
Hp	Horse power
Hz	Hertz
IHO	International Hydrographic Organization
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
ISS-2000	Integrated Survey System 2000
ISSC	Integrated Survey System Computer
JD	Julian Day
kHz	kiloHertz
kW	kilowatt
LA	Louisiana
LOA	Length Over All
MBES	MultiBeam Echo Sounder
MVE	Multi-View Editor
MVP	Moving Vessel Profiler
NAS	Network Attached Storage
NJ	New Jersey
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
ONSWG	Open Navigation Surface Working Group
PFM	Pure File Magic

POS/MV	Position Orientation System/Marine Vessels
QA	Quality Assurance
QC	Quality Control
RI	Rhode Island
RPM	Revolutions Per Minute
SABER	Survey Analysis and area Based EditoR
SAT	Sea Acceptance Tests or Swath Alignment Tool
SN	Serial Number
SS-ACQ	Side Scan Acquisition computer
SSP	Sound Speed Profile
SV&P	Sound Velocity and Pressure Sensor
TPE	Total Propagated Error
TPU	Total Propagated Uncertainty or Transceiver Processing Unit
TTL	Transistor-Transistor Logic
UPS	Uninterruptible Power Supply
UTC	Coordinated Universal Time
XML	eXtensible Markup Language
XTF	eXtended Triton Format

PREFACE

This Data Acquisition and Processing Report (DAPR) applies to hydrographic sheets H12727, H12728, H12729 and H12730. Survey data were collected from September 2015 through December 2015. The GSF files delivered for H12727, H12728, H12729 and H12730 are GSF version 03.06. CARIS HIPS and SIPS version 8.1.11 and later versions are compatible with GSF version 03.06.

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.

Note that a modification to the Leidos Task Order was made on 17 September 2015 which added hydrographic sheets H12731 and H12838 to Project No. OPR-K371-KR-15. However, no data were collected in 2015 on sheets H12731 and H12838, and therefore a revised DAPR will be submitted once those sheets are collected and delivered.

The Hydrographic Survey Project Instructions for H12727, H12728, H12729 and H12730 reference the April 2014 version of the *"NOS Hydrographic Surveys Specifications and Deliverables"* (HSSD). The Hydrographic Survey Project Instructions for sheets H12731 and H12838 reference the May 2015 HSSD version. Leidos was granted permission by the Contracting Officer's Representative (COR) on 26 October 2015 to deliver all six sheets (H12727, H12728, H12729, H12730, H12731, and H12838) to the May 2015 HSSD version. 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 7 (Service Pack 1) 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 bathymetry, backscatter, 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. Side scan sonar data were acquired using Klein's **SonarPro** software running on the Leidos Side Scan Acquisition computer (SS-ACQ) which also consisted of a quad core processor computer with the Windows 7 (Service Pack 1) operating system. The SS-ACQ was integrated with the ISSC for timing and navigation.

A.2 DATA PROCESSING

Post processing was performed on the survey vessel (*M/V Atlantic Surveyor)* and in the Newport, RI, Data Processing Center (DPC). Multibeam and side scan data were processed and reviewed on computers with the Linux operating system, which ran Leidos' **SABER** (Survey Analysis and Area Based EditoR) software. 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. See Appendix II for a detailed data processing flow diagram.

A.3 SURVEY VESSEL

For this project, Leidos employed one survey vessel, the *M/V Atlantic Surveyor* (Figure A-1). Table A-1 presents the characteristics for the vessel.

The *M/V Atlantic Surveyor* 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.

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

Table A-1: Survey Vessel Characteristics; *M/V Atlantic Surveyor*

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

Leidos outfitted the *M/V Atlantic Surveyor* with the following major data acquisition systems for the survey effort:

- POS/MV 320 version V4 and IMU type 2
- RESON Seabat 7125 SV and RESON Seabat 8101 ER multibeam sonars
- Klein 3000 dual frequency side scan sonar
- Moving Vessel Profiler 30 (MVP30) manufactured by ODIM Brooke Ocean, a part of the Rolls-Royce Group

The side scan winch and four International Organization for Standardization (ISO) containers were secured on the aft deck. The first 20-foot container was used as the real-time survey data acquisition office, the second 20-foot container was used for the onboard data processing office, and the third 20-foot 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 Seabat 7125 SV transducer and RESON SVP 70 surface sound velocity sensor, and subsequently the RESON Seabat 8101 ER, were hull-mounted approximately amidships, port of the vessel's keel. The MVP30 was mounted on the starboard stern quarter. Configuration parameters, offsets, and installation diagrams for all equipment are included in Section C of this Report.

Further details about the vessel, acquisition systems and software, and processing systems and software are provided in the sections below.

A.4 LIDAR SYSTEMS AND OPERATIONS

Leidos did not use a lidar system on these surveys.

A.5 MULTIBEAM SYSTEMS AND OPERATIONS

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

- Windows 7 workstation (ISSC) for data acquisition, system control, survey planning, survey operations, and real-time Quality Control (QC).
- A RESON Seabat 7125 SV multibeam system with a RESON SVP 70 sound speed sensor (see Appendix IV for the RESON SVP 70 calibration reports). The RESON Seabat 7125 SV multibeam system was installed onboard the *M/V Atlantic Surveyor* and used through 28 October 2015, at which time the system was removed from the ship and sent to RESON for factory repair and servicing. The RESON Seabat 7125 SV is a single frequency system operating at 400 kilohertz (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 Seabat 7125 SV was set to the 256 beams Equi-Angular mode during survey operations. The maximum ping rate was manually set to between 20 Hertz (Hz) and 50 Hz. During item investigations 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.

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

- A RESON SeaBat 8101 ER multibeam system was installed onboard the *M/V Atlantic Surveyor* on 30 October, 2015 and used through the end of survey operations in 2015 (15 December 2015). The RESON SeaBat 8101 ER is a 240 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 based on water depth and survey speed to yield the highest ping rate while maintaining a 120 degree usable swath (60 degrees per side).

RESON SeaBat 8101 ER	
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).

POS/MV 320	
System	**Version/Model/SN**
MV-320	Ver4
SERIAL NUMBER	2575
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

- Trimble 4000 DS GPS Receiver (Serial Number 3504A09516) with a Trimble ProBeacon Differential Receiver (Serial Number 220159406) (secondary positioning sensor).
- MVP30 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.7 for additional details concerning sound speed and Appendix IV for the SV&P Sensor calibrations).

MVP30	
System	**Version/Model/SN**
MVP	30
Software	2.21
SV&P Sensors	4523 5332 5454 5455

- Seabird Model SBE 19 Conductivity, Temperature, Depth (CTD) profilers were used during the Sea Acceptance Tests (SAT) but were not used during any hydrographic data collection (See Section A.7 for additional details concerning sound speed and Appendix IV for the CTD Sensor calibrations). Seabird SBE-19 serial number 193607-0565 remained onboard the *M/V Atlantic Surveyor* for the duration of the survey season as a backup sensor to the MVP30.

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

- Monarch shaft RPM sensors.
- 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 1 to 10 degrees (5 degrees per side) or Class 2 to 120 degrees (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.

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 80 meters for use with a side scan range setting of 50 meters. Using ±60 degrees as the acceptable swath, 100 percent multibeam coverage was not achieved nor required by the Project Instructions.

All multibeam 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.

File names were changed at the end of each line. This protocol provided the ability to easily associate each consecutive multibeam 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. If a file was not manually changed between a main scheme and crossline, the multibeam GSF file was split 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 GSF file or set of files. In all cases, main scheme and crossline data were delivered in separate GSF files.

When a multibeam 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 DR.

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 processing computers were backed-up to an external hard drive and digital magnetic tape approximately every week. The external hard drives and the digital magnetic tape back-ups were shipped approximately every 12-14 days to the Leidos DPC in Newport, RI for final processing and archiving.

Leidos continuously logged multibeam 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 DR.

Lead line comparisons were conducted to provide Quality Assurance (QA) for the RESON Seabat 7125 SV and the RESON Seabat 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 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

- For both the RESON Seabat 7125 SV and RESON Seabat 8101 ER multibeam systems, ten depth measurements were acquired on each side of the vessel at the fore-aft location 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" (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 (centimeter resolution). The measurements taken provide the distance from the seafloor to the top of a 0.02 meter square metal bar protruding from the port and starboard side's main deck. At least ten separate depth measurements and corresponding times were recorded for both the port and starboard sides. 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 were recorded in the lead line spreadsheet, the Leidos **ExamGSF** program was 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 DR.

In accordance with the May 2015 *NOS HSSD* and the Project Instructions Leidos collected multibeam backscatter with all GSF data acquired by the RESON Seabat 7125 SV and RESON Seabat 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. Please note for backscatter review, there is a known issue with Fledermaus Geocoder Toolbox (FMGT) which requires GSF files to have an extension of .gsf to be loaded into the program. Leidos has included a Read_Me.txt file which provides directions on how to change the extension on all of the files in a directory quickly. This Read_Me is located in the following folder for each sheet: "HXXXXX\Data\Processed\Bathymetry_&_SSS\MBES\MBES_Files".

A.6 SIDE SCAN SONAR SYSTEMS AND OPERATIONS

These survey operations were conducted at set line spacing optimized to achieve 100% side scan sonar coverage.

The side scan sonar systems used for these surveys included:

- A towed Klein 3000 digital side scan sonar towfish (SN 534 and 535) with a Klein K1 K-wing depressor.
- Windows 7 workstation (SS-ACQ) running Klein's **SonarPro** software for data acquisition, side scan system control, logging of side scan sonar data, and real-time Quality Control (QC).
- Klein Transceiver Processing Unit (TPU) (SN 418 and 420).
- 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).

The Klein 3000 is a conventional dual frequency side scan sonar system. The 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 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 Hz. Based on these ping rates, maximum survey speeds were established for each range scale setting to ensure that an object 1-meter of a side on the sea floor would be independently ensonified a minimum of three times per pass 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, and therefore the survey speeds were typically less than 8.5 knots.

During survey operations, 16-Bit digital data from the TPU were acquired, displayed, and logged by the Leidos SS-ACQ 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 180 minutes or manually at the completion of a survey line, whichever occurred first.

These XTF 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 daily and magnetic tape approximately every three days. The external hard drive and the digital magnetic tape back-ups were shipped to the DPC in Newport, RI, during port calls.

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)*, Julian Day that the data file was collected, calendar date, and time that the file was created. For example in side scan file "as320_151116162600.xtf":

- "as" refers to survey vessel *M/V Atlantic Surveyor.*
- 320 refers to Julian Day 320.
- 151116 refers to the year, month and day (YYMMDD), 16 November 2015.

- 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 DR.

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 Klein's **SonarPro** to **ISS-2000**), and the Course Made Good (CMG) of the vessel. The calculated towfish position was sent to the SS-ACQ 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 (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 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.

A.7 SOUND SPEED PROFILES

A Moving Vessel Profiler 30 (MVP30) with an Applied Microsystems Smart SV&P 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 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 DR."

The **Environmental Manager** module in **ISS-2000** 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 MVP30 sound speed sensor was towed behind the vessel where the upper 3-meters of the water column were mixed by the vessel's propellers. 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 as needed. 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. 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, Seabird CTD, and RESON SVP-70 sensors used on these surveys or used during Sea Acceptance Tests. Copies of the calibration records are in Appendix IV. Sound speed data are included with the survey data delivered for each sheet.

- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 4523, pre-survey calibration date: 12 March 2015.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5332, pre-survey calibration date: 12 March 2015.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5454, pre-survey calibration date: 12 March 2015.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5455, pre-survey calibration date: 12 March 2015.
- Seabird Electronics, Inc., CTD, Serial Number 193607-0565, pre-survey calibration date: 7 March 2015, post-survey calibration date 23 January 2016.
- Seabird Electronics, Inc., CTD, Serial Number 194275-0648, pre-survey calibration date: 7 March 2015 , post-survey calibration date 22 January 2016.
- Seabird Electronics, Inc., CTD, Serial Number 1920459-2710, pre-survey calibration date: 12 March 2015 , post-survey calibration date 23 January 2016.
- RESON SVP70, Serial Number 0213030; pre-survey calibration date: 23 March 2015.
- RESON SVP70, Serial Number 0213031; pre-survey calibration date: 23 March 2015.

Separates Section II of the DR for each sheet will include any subsequent calibration reports received after the delivery of this DAPR.

A.8 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. Leidos did not modify locations from the recommended locations provided by NOAA, unless otherwise noted in each sheet's DR. 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). Digital photographic images of each bottom sample are also included in the S-57 Feature File for each sheet.

A.9 DATA ACQUISITION AND PROCESSING SOFTWARE

Data acquisition was carried out using the Leidos **ISS-2000** software (Version 5.1.0.7.0) for Windows 7 operating systems to control acquisition navigation, data time tagging, and data logging.

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

Table A-2: SABER Versions and Installations Dates

SABER and Survey Planning Version	Date Version Installed In Newport, RI	Date Version Installed On *M/V Atlantic Surveyor*	Software Use
5.2.0.14.1	09 September 2015	01 September 2015	General

SABER and Survey Planning Version	**Date Version Installed In Newport, RI**	**Date Version Installed On *M/V Atlantic Surveyor***	**Software Use**
5.2.0.14.6	28 October 2015	28 October 2015	General
5.2.0.14.13	01 February 2016	N/A	General

Klein's **SonarPro** Version 12.1, was used for side scan data acquisition.

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

A.10 SHORELINE VERIFICATION

Shoreline verification was not required for these surveys.

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 acquisition, survey watchstanders continuously monitored the systems, checking for errors and alarms. Thresholds set in the **ISS-2000** system parameters alerted the watchstander 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 **ISS-2000** 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 watchstander and automatically recorded into a message file. Approximately every 2-3 hours the acquisition watchstanders completed checklists to verify critical system settings and ensure valid data collection.

Following data collection, initial data processing began onboard the *M/V Atlantic Surveyor*. This included the first level of quality assurance:

- Initial swath editing of multibeam data flagging invalid pings and beams.
- Application of delayed heave (Applanix *TrueHeave*™).
- Computation of Total Propagated Uncertainty (TPU) for each depth value in the multibeam data.
- Generation of a preliminary Pure File Magic (PFM) CUBE surface.
- Second review and editing of multibeam data using the PFM CUBE surfaces.
- 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 and designated soundings.

- Generation of multibeam and side scan track line 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.
- Hydrographer review of side scan contact files.
- Adjustments to time windows based on data quality.
- Generation of preliminary side scan coverage mosaics.
- Identification of holidays in the side scan coverage.

On a daily basis, the multibeam data were binned into 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 every two weeks a complete backup of all raw and processed survey data were sent to the Leidos DPC in Newport, RI. Complete analysis of the data at the Newport facility included the following steps:

- 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 one-meter CUBE PFM surface for analysis of coverage, areas with high TPU, and features.
- Crossline analysis of multibeam data.
- Comparison with adjoining sheets.
- Generation of final one-meter CUBE PFM surface.
- Generation of S-57 feature file.
- Comparison with existing charts.
- Quality control reviews of side scan data and contacts.
- Generation of final coverage mosaics of side scan sonar data.
- Correlation of side scan contacts with multibeam features and designated soundings.
- 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-4 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 Seabat 7125 SV

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

Parameter	Value	Units
Vertical Navigation Error (uncertainty)	0.20*	Meters
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SVP Measurement Error (uncertainty)	1.00	Meters/second
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters
Settlement & Squat Error (uncertainty)	0.05	Meters
Predicted Tide Measurement Error (uncertainty)	0.20	Meters
Observed Tide Measurement Error (uncertainty)	0.11	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.20	Meters
SEP Uncertainty	0.15	Meters

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

Table B-2: RESON Seabat 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-3: *M/V Atlantic Surveyor* Error Parameter File (EPF) for the RESON Seabat 8101 ER

Parameter	Value	Units
VRU Offset – X	0.340	Meters
VRU Offset – Y	0.120	Meters
VRU Offset – Z	-1.640	Meters
VRU Offset Error – X (uncertainty)	0.005	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	4.60	Meters
Antenna Offset – Y	-0.54	Meters

Parameter	Value	Units
Antenna Offset – Z	-8.02	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
Surface Sound Speed Error (uncertainty)	1.00	Meters/second
SVP Measurement Error (uncertainty)	1.00	Meters/second
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters
Settlement & Squat Error (uncertainty)	0.05	Meters
Predicted Tide Measurement Error (uncertainty)	0.20	Meters
Observed Tide Measurement Error (uncertainty)	0.11	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.20	Meters
SEP Uncertainty	0.15	Meters

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

Table B-4: RESON Seabat 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)	0.05	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

B.2 MULTIBEAM 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 (onboard the *M/V Atlantic Surveyor*) with the review of multibeam data files to flag erroneous data such as noise, flyers or fish, and to designate features or designated soundings. Please note that the GSF files collected and delivered for sheets H12727, H12728, H12729 and H12730 are GSF version 03.06. CARIS HIPS and SIPS version 8.1.11 and later versions are compatible with GSF version 03.06. The bathymetry data were reviewed and edited, on-board the vessel, 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 one-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.

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 one-meter node PFM CUBE surface for analysis using **SABER** and **MVE**. The one-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 one-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 DR 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 file(s) for final delivery.

B.2.1 Multibeam Coverage Analysis

Bathymetric coverage analysis was conducted during initial data processing and on the final CUBE surface to identify areas where (if any) data coverage holidays exceeded the allowable three by three nodes in accordance with Section 5.2.2.2 of the HSSD for complete coverage. As previously stated in Section A.6, these survey operations were conducted at line spacing optimized to achieve 100% side scan sonar coverage.

The **SABER Gapchecker** utility was run on the CUBE surface to identify and flag any areas of data holidays exceeding the allowable three by three 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 three by three node holidays detected. Results of the bathymetry coverage analysis are presented in each sheet's DR.

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 80% of all nodes contained five or more soundings, ensuring the requirements for Complete Coverage Option 2 (side scan sonar coverage with concurrent multibeam) coverage as specified in Sections 5.2.2.2 of the HSSD were met. A complete analysis of the results of the **Frequency Distribution** tool is provided in the DR for each sheet.

B.2.2 Junction Analysis

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 sheet.

B.2.2.1 Main scheme to Crossline Comparisons

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. Crosslines were acquired at varying time periods throughout the survey period so that the crossline analyses could provide an indication of any potential temporal or systematic issues (if any) that may affect the data. 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)

B.2.2.2 Contemporary Sheet to Sheet Junctions

Junction analysis was conducted between contemporary survey sheets assigned in the Project Instructions (listed in Table B-5), as well as between sheets for this project where the data have been fully processed (Figure B-1). For junction analysis, the current data were binned at a one-meter grid resolution using the CUBE algorithm. For the assigned contemporary sheets, final smooth sheet XYZ data (irregular spacing) were downloaded from the NGDC website. These XYZ files were imported into CARIS and a 50-meter base surface created. The surface was then exported to a 50-meter BAG file. The following binned grids were created and used for junction analysis:

- All online data collected during survey (full valid swath, ±60° cutoff) one-meter CUBE PFM
- Assigned contemporary sheets final smooth sheet XYZ data converted to 50-meter BAG files

Table B-5: Contemporary Sheet Junctions Assigned for OPR-K371-KR-15

Registry Number	Scale	Year	Field Unit	Relative Location
H10572	20000	1994	NOAA Ship MOUNT MITCHELL	NE
H10804	20000	1999	John E. Chance & Associates	W
H10834	20000	1999	C & C Technologies, Inc.	N
H10851	20000	1999	C & C Technologies, Inc.	NW
H10891	20000	1999	C & C Technologies, Inc.	E
H10948	20000	2000	Fugro GeoServices, Inc.	SW

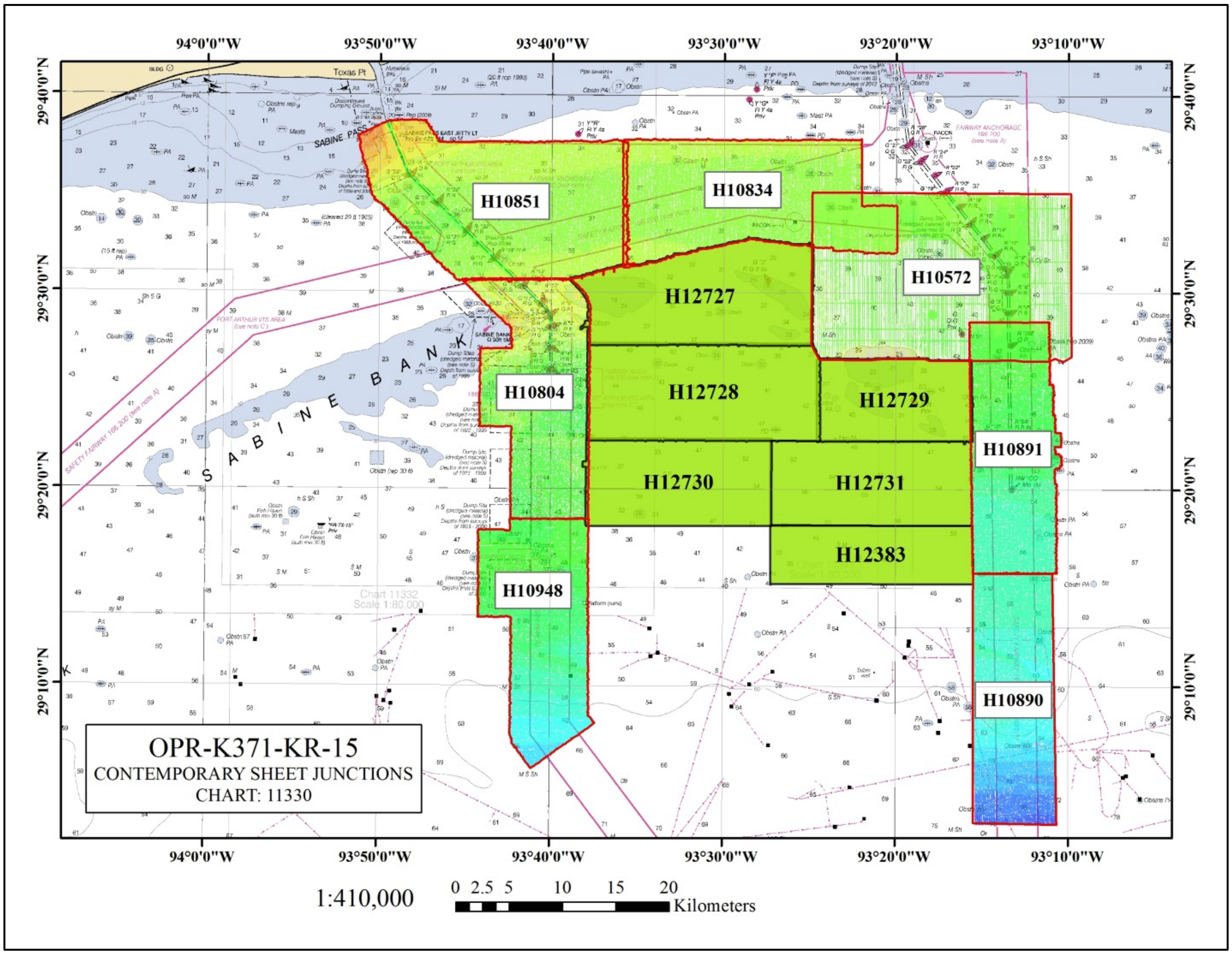

Figure B-1: Contemporary Sheet Junctions Assigned for OPR-K371-KR-15

B.2.3 Crossing Analysis

A beam-to-beam comparison of crossline data to main scheme 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 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. Then Leidos converted the PFM grid to a BAG file using the **SABER Convert PFM to BAG** utility. This process exports the CUBE Depth Surface and Hypothesis Final Uncertainty Surface, as well as additional child layers, to the BAG as outlined in HSSD Section 5.2.1. The 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, the associated Hypothesis Final Uncertainty surface, and optionally several other surfaces 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 files. 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.

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).

In addition to the depth and uncertainty surfaces, other child layers can also be converted to the BAG. These surfaces have been grouped with the BAG file structure. 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 are version 1.5.1, compressed, and include both the Elevation Solution Group surfaces and the Node Group surfaces.

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.

B.2.6 S-57 Feature File

Included with each sheet's delivery is an 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 F 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 surveyed areas of Project OPR-K371-KR-15 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 quality controlled with **dKart Inspector**, CARIS **Easy View**, and SevenCs **SeeMyDENC**.

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 depth flag codes. Table B-4 represents commonly used definitions for these GSF ping flags, as well as their mapping to CARIS profile 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-6: 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.

GSF Beam Flags		CARIS HIPS Flag	
Bitmask	Comments	Name	Comments
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-7: 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 a 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 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** (detailed in Table B-8). 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 were 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-8: Detection Parameters File Used for ACD Data Processing

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	25		
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

B.3.2.2 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-2) 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.

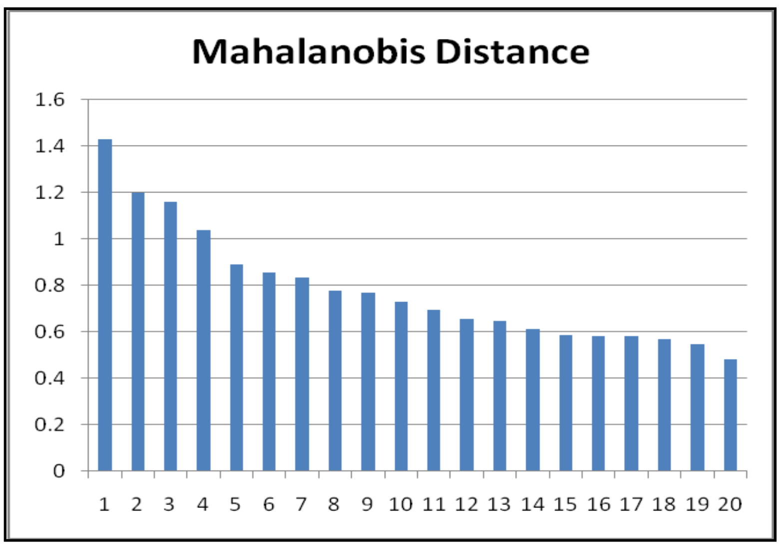

Figure B-2: Mahalanobis Distance of Top Twenty Parameters

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 fell between zero and one, a user assigned value (decision method) determined which detections were 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-3 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.

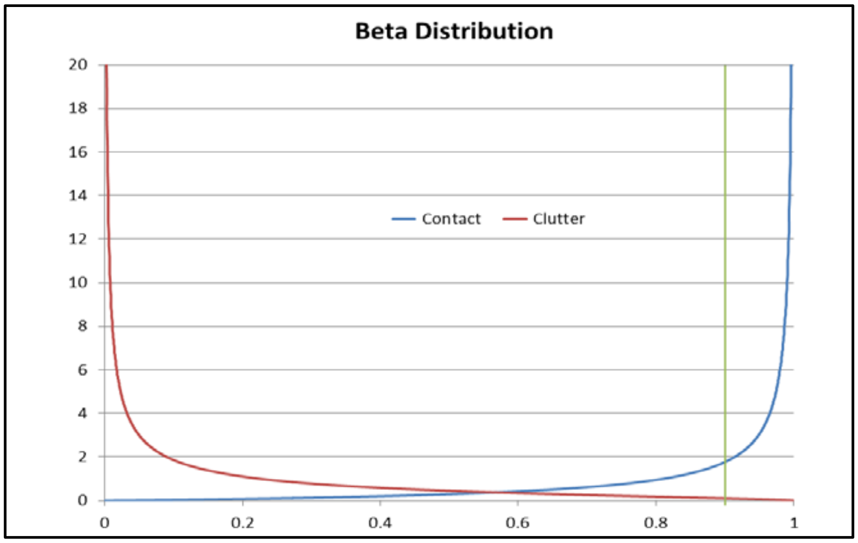

Figure B-3: Decision Method Based on Beta Distributions

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 **SABER's Imagery Review** and **Contact Review** programs. Within **Imagery Review**, the contact detections were overlain on the side scan sonar record. The side scan data within **Imagery Review** was down sampled 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 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 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 DR.

B.3.4 Side Scan Contact Analysis

During side scan data review, the hydrographer used the **Contact Review** program to review each contact 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. The contact and all surrounding displayed side scan data are always opened at full resolution. 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.

B.3.6 Side Scan Coverage Analysis

The Project Instructions required 100% side scan coverage. Two hundred percent side scan coverage was obtained over assigned objects and for disproving charted objects. The 200% side scan coverage was verified by generating two separate 100% coverage mosaics. The first 100% side scan coverage consisted of all initial survey lines while the second 100% side scan coverage consisted of any additional coverage over discrete objects. 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 DR.

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 and Figure C-2 show the *M/V Atlantic Surveyor* sensor configuration and the vessel offsets for the RESON Seabat 7125 SV and RESON Seabat 8101 ER. The vessel offsets are tabulated in Table C-1 and Table C-2. All measurements are in meters. Both the RESON transducers were hull-mounted approximately amidships, just port of the keel, when in use. Offset measurements were made from the POS/MV IMU to the acoustic center of the each systems transducer. See Appendix I for details on the vessel offsets survey.

The Leidos **ISS-2000** and the POS/MV software utilize a coordinate system where “Z” is defined as positive down, “X” is defined as positive forward, and “Y” is defined as positive to starboard. Table C-1 and Table C-2 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.

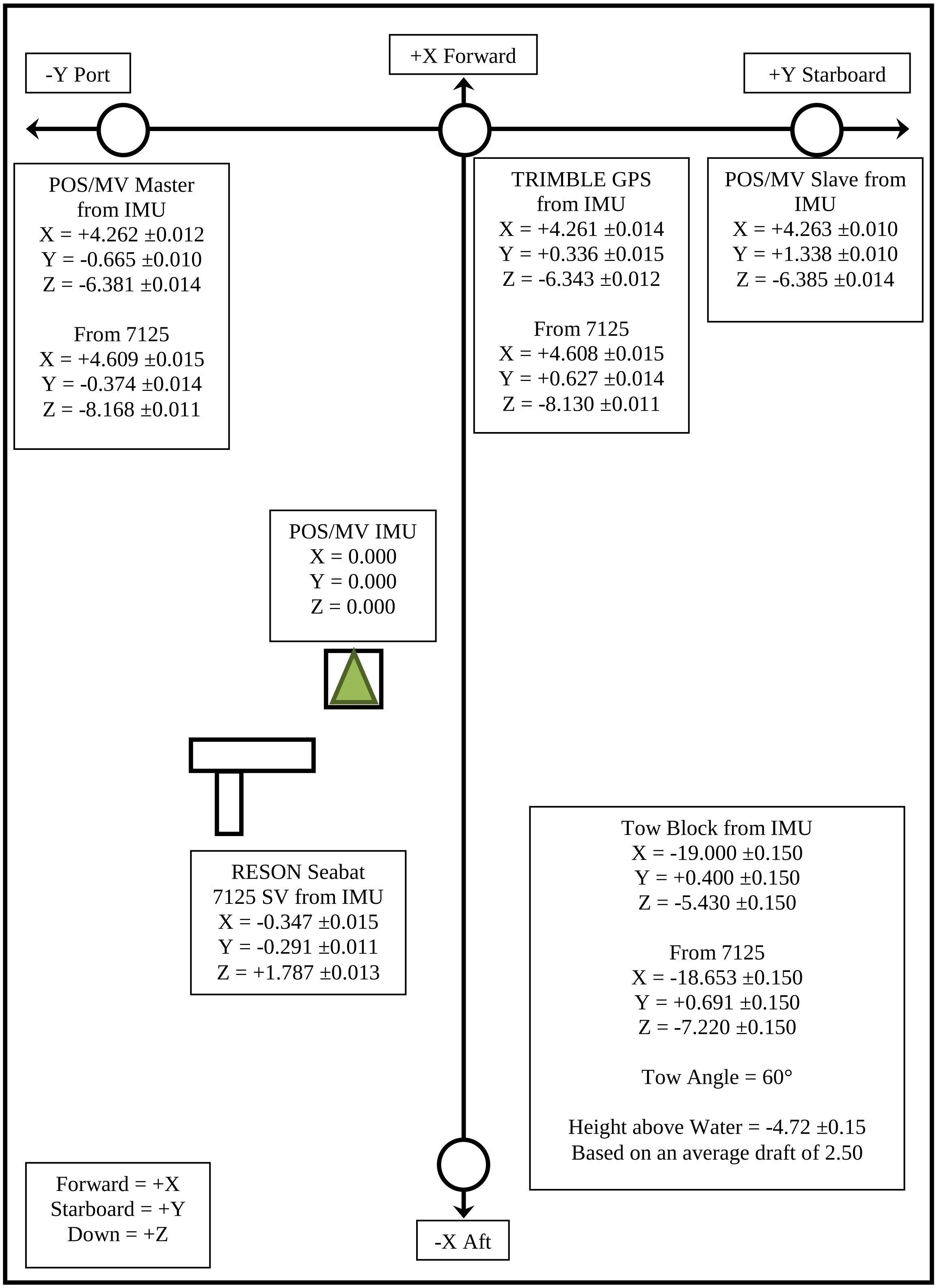

Figure C-1: 2015 Configuration and Offsets of *M/V Atlantic Surveyor* Sensors for the RESON Seabat 7125 SV (measurements in meters with 1-sigma uncertainty)

Table C-1: 2015 *M/V Atlantic Surveyor* Antenna and RESON Seabat 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	
Reference to Primary GPS Lever Arm (IMU to Master GPS Antenna)			X	4.262 ±0.012
			Y	-0.665 ±0.010
			Z	-6.381 ±0.014
Reference to Vessel Level Arm (IMU to RESON Seabat 7125 SV Transducer)			X	-0.347 ±0.015
			Y	-0.291 ±0.011
			Z	+1.787 ±0.013
Reference to Center of Rotation Lever Arm (IMU to vessel CG)			X	-0.900
			Y	+0.365
			Z	-0.780
Reference to Sensor 1 Lever (IMU to RESON Seabat 7125 SV Transducer)			X	-0.347 ±0.015
			Y	-0.291 ±0.011
			Z	+1.787 ±0.013
Trimble GPS Antenna from RESON Seabat 7125 SV 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 Seabat 7125 SV Transducer. Z is height above water).	X	-18.653 ±0.150		
	Y	+0.691 ±0.150		
	Z	-4.720 ±0.150		

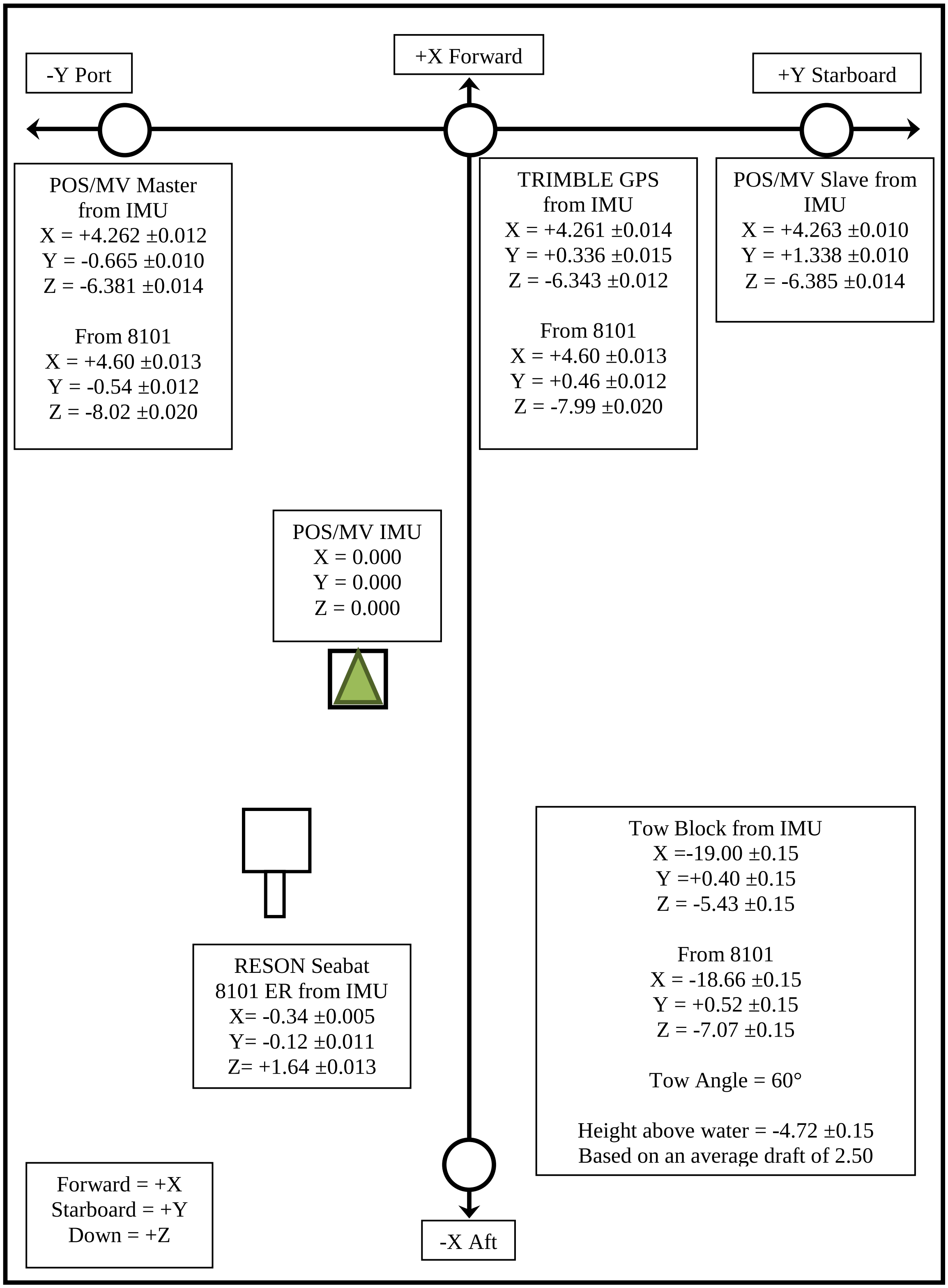

Figure C-2: 2015 Configuration and Offsets of *M/V Atlantic Surveyor* Sensors for the RESON Seabat 8101 ER (measurements in meters with 1-sigma uncertainty)

Table C-2: 2015 *M/V Atlantic Surveyor* Antenna and RESON Seabat 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	
Reference to Primary GPS Lever Arm (IMU to Master GPS Antenna)			X	+4.262 ±0.012
			Y	-0.665 ±0.010
			Z	-6.381 ±0.014
Reference to Vessel Level Arm (IMU to RESON Seabat 8101 ER Transducer)			X	-0.34 ±0.005
			Y	-0.12 ±0.011
			Z	+1.64 ±0.013
Reference to Center of Rotation Lever Arm (IMU to vessel CG)			X	-0.900
			Y	+0.365
			Z	-0.780
Reference to Sensor 1 Lever (IMU to RESON Seabat 8101 ER Transducer)			X	-0.34 ±0.005
			Y	-0.12 ±0.011
			Z	+1.64 ±0.013
Trimble GPS Antenna from RESON Seabat 8101 ER Transducer	X	+4.60 ±0.013		
	Y	+0.46 ±0.012		
	Z	-7.99 ±0.020		
A-Frame Tow Block (X and Y from RESON Seabat 8101 ER Transducer. Z is height above water).	X	-18.66 ±0.150		
	Y	+0.52 ±0.150		
	Z	-4.72 ±0.150		

C.1 STATIC AND DYNAMIC DRAFT MEASUREMENTS

C.1.1 Static Draft

Figure C-3 and Figure C-4 show the draft determination for the *M/V Atlantic Surveyor*. When installed, the RESON Seabat 7125 SV transducer was hull-mounted 3.50 meters below the vessel's main deck. When installed, the RESON Seabat 8101 ER transducer was hull mounted 3.28 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 Watchstander 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.

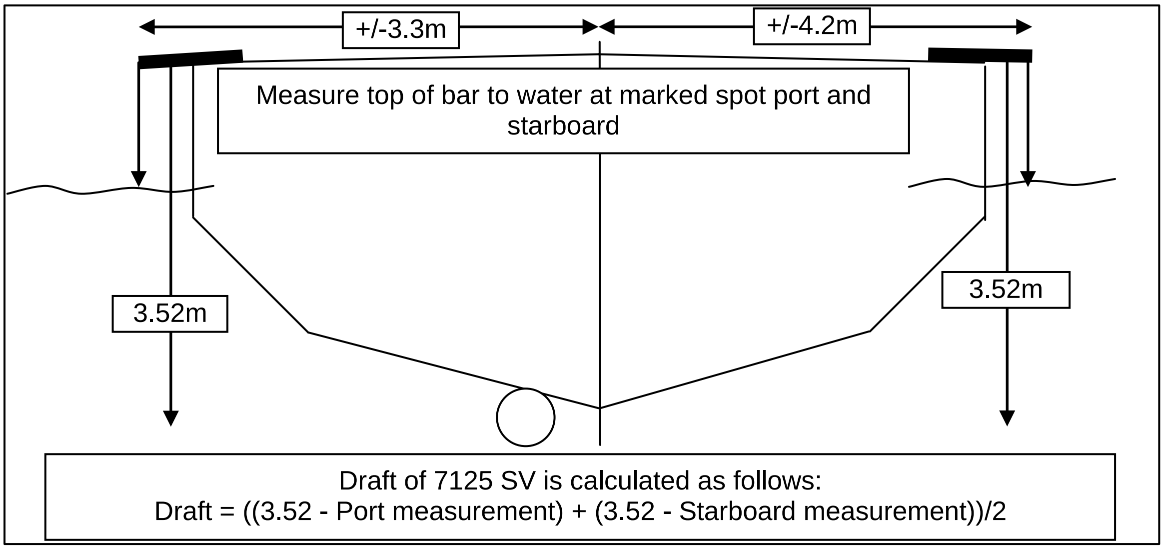

Figure C-3: *M/V Atlantic Surveyor* RESON Seabat 7125 SV Draft Determination

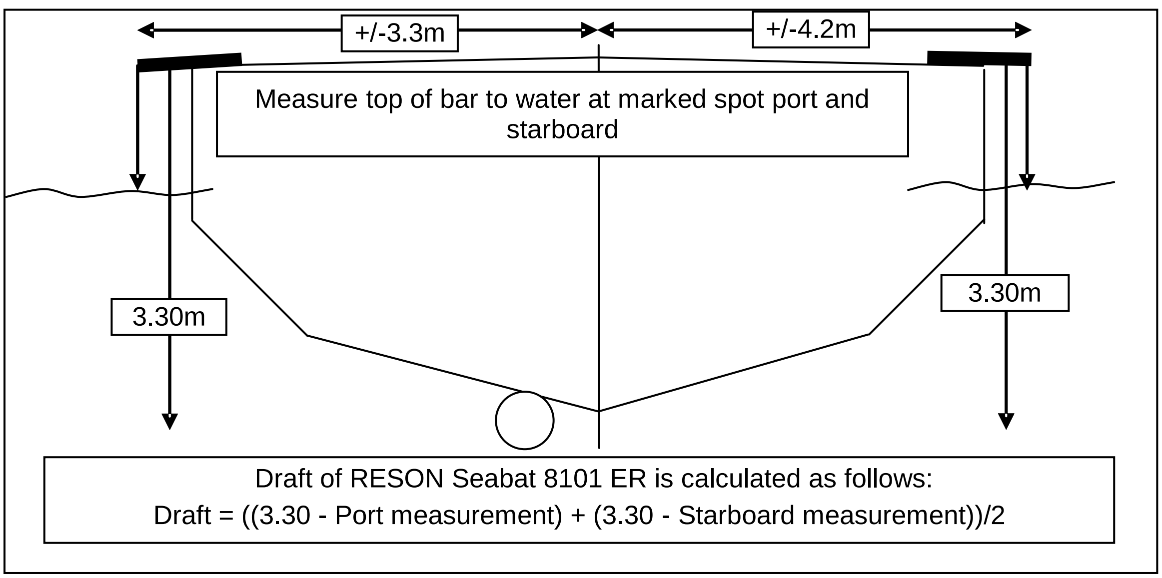

Figure C-4: *M/V Atlantic Surveyor* RESON Seabat 8101 ER Draft Determination

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.

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 in post processing to the data for that day. When the JD rollover occurred in the middle of a survey line, the first file of the new day was given the same prorated draft as the previous day. This procedure ensured that the static draft for every survey line was constant and did 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 used to apply the calculated prorated draft value to multibeam GSF files as appropriate. 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, 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. This was done to ensure the expected prorated static draft values were correctly applied to all multibeam data.

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 DR. The static draft applied to each individual GSF file is reported in the Multibeam Processing Log for each sheet.

C.1.2 Dynamic Draft

During the SAT performed for the *M/V Atlantic Surveyor*, dynamic draft values were confirmed using an average of eight previous year’s settlement and squat data for this vessel (see Appendix I for details).

Table C-3 summarizes the shaft RPM, depth corrector, approximate speed, and the 2015 SAT multibeam files (JD 247) used to confirm the averaged dynamic draft values in use.

These values confirmed 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-3: 2015 *M/V Atlantic Surveyor* Settlement and Squat Confirmation

RPM	FILENAME	SQUAT CORRECTOR USED	DELTA FROM DIFFERENCE GRIDS	1-SIGMA
0	asmba15247.d27	0.00	NA	NA
140	asmba15247.d28	0.00	0.005	0.008587
	asmba15247.d29			
180	asmba15247.d30	0.02	-0.017	0.022043
	asmba15247.d31			
250	asmba15247.d32	0.03	-0.015	0.011831
	asmba15247.d33			
300	asmba15247.d36	0.06	+0.023	0.011642
	asmba15247.d37			
340	asmba15247.d38	0.09	+0.032	0.009865
	asmba15247.d39			
380	asmba15247.d40	0.11	+0.034	0.013842
	asmba15247.d41			
AVERAGE STANDARD DEVIATION				0.016116

C.1.3 Speed of Sound

A Moving Vessel Profiler 30 (MVP30) manufactured by ODIM Brooke Ocean, a part of Rolls-Royce Group, along with an AML Oceanographic Smart Sound Velocity and Pressure (SV&P) sensor was used to determine sound speed profiles for corrections to multibeam sonar soundings.

Confidence checks were obtained periodically (every 6-13 days) with two or more consecutive casts acquired with different SV&P sensors. After downloading the sound speed profile (SSP) comparison casts, graphs and tabulated lists were used to compare the corresponding SSP data.

During multibeam 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 system for use).

Once applied, the multibeam system used the SSP 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 SSP casts were taken at the beginning of each survey leg, at approximately two-hour intervals, and at the end of each survey leg.

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 observed and corrected during real-time data acquisition. Proper sound speed application and effects were also analyzed throughout the survey during post processing.

SSP files (.svp) are delivered in a separate folder on the delivery drive; "HXXXXX/Data/Processed/SVP/CARIS_SSP". These files contain concatenated SSP data that has been formatted for use in CARIS. The CARIS SSP file names are designated based on the purpose of the cast.

C.2 MULTIBEAM CALIBRATIONS

A Sea Acceptance Test (SAT) was conducted for each sonar installation prior to the start of data acquisition on this project.

The SAT for the *M/V Atlantic Surveyor* integrated with the RESON Seabat 7125 SV multibeam system was conducted from 03 September 2015 (JD 246) to 07 September 2015 (JD 250) in New Jersey and the results verified in Louisiana from 23 September 2015 (JD 266) to 24 September 2015 (JD 267).

On 27 October 2015 (JD 300) the RESON Seabat 7125 SV multibeam system began to exhibit degraded performance, followed by a complete system failure which was not able to be resolved in the field. After returning to dock for further troubleshooting it was determined that the system was in need of factory service and repair. On 28 October 2015 (JD 301) the RESON Seabat 7125 SV sonar was removed from the ship's hull mount by divers and then the entire system was removed from the ship and sent to RESON for factory repair and servicing.

On 30 October 2015 (JD 303) the RESON Seabat 8101 ER multibeam system was received onboard the *M/V Atlantic Surveyor.* The RESON Seabat 8101 ER sonar was then installed on the ship's hull mount by divers and the entire sonar system integrated into the survey acquisition system. A SAT for the *M/V Atlantic Surveyor* integrated with the RESON Seabat 8101 ER multibeam system was then conducted from 30 October 2015 (JD 303) to 02 November 2015 (JD 306).

SAT for both the RESON Seabat 7125 SV and the RESON Seabat 8101 ER multibeam systems included at least, but not limited to, the following:

- Ping timing test to verify that no timing errors existed within the survey system
- Multibeam patch test to determine bias values for roll, pitch, and heading
- Beam-by-beam analysis of the multibeam data performed with the **SABER ACCUTEST** program
- Small survey to analyze multibeam accuracies after the installations.

During the original SAT conducted from 03 September 2015 (JD 246) to 07 September 2015 (JD 250) in New Jersey, settlement and squat values for the dynamic draft of the vessel were confirmed. The settlement and squat values confirmed from that test (referenced in Table C-3) remained the same throughout the completion of data acquisition in 2015.

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 Seabat 7125 SV was completed on 02 September 2015 (JD 245) to verify that no timing errors existed within the survey system (see Appendix II for details). An additional ping timing test was completed for the installation of the RESON Seabat 8101 ER on 31 October 2015 (JD 304) to verify that no timing errors existed within the survey system (see Appendix II for details).

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 Seabat 7125 SV or the RESON Seabat 8101 ER) and the 1PPS timing pulses from the POS/MV.

These tests demonstrated that all RESON Seabat 7125 SV GSF ping times and RESON Seabat 8101 ER GSF ping times matched the corresponding IRIG-B event times. (Figure C-5 and Figure C-6).

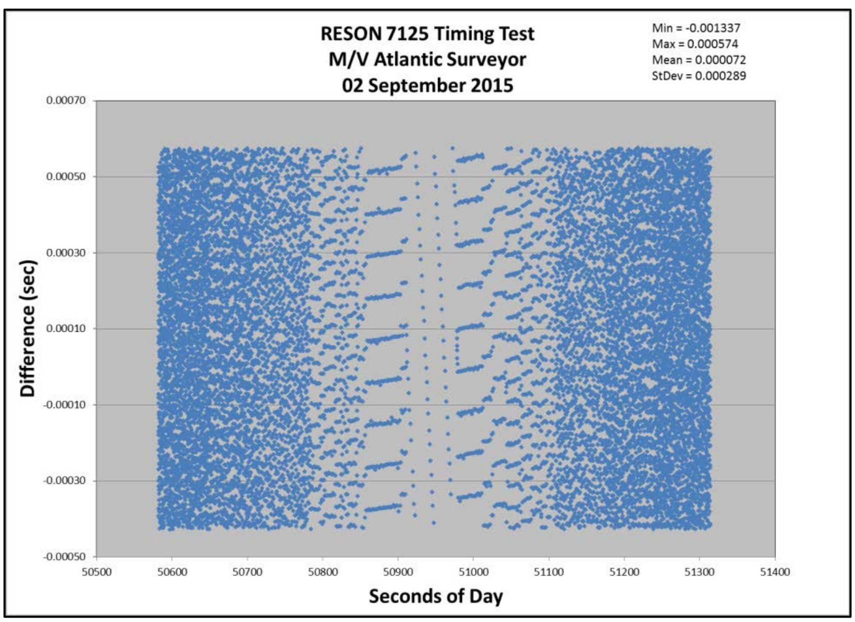

Figure C-5: 02 September 2015 RESON Seabat 7125 SV Timing Test Results (time differences of ping trigger event vs. ping time tag from GSF)

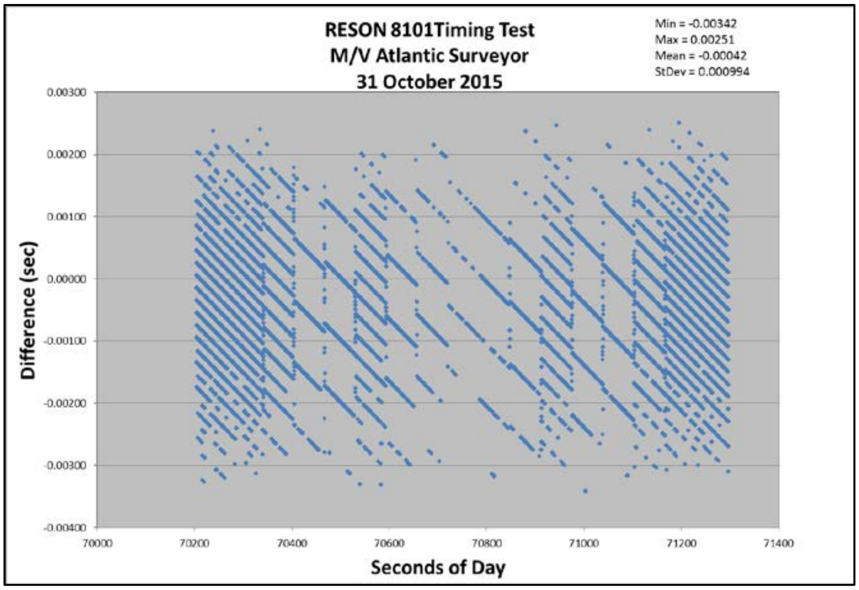

Figure C-6: 31 October 2015 RESON Seabat 8101 ER Timing Test Results (time differences of ping trigger event vs. ping time tag from GSF)

C.2.2 Multibeam Bias Calibration (Alignment)

Roll, pitch, and heading biases were determined on 04 September 2015 (JD 247) for the RESON Seabat 7125 SV installed on the *M/V Atlantic Surveyor* (see Appendix II for details). The results are presented in Table C-4. The bias results were verified upon arrival in Louisiana on 23 to 24 September 2015 (JD 266 to 267). The verification results are presented in Table C-5.

Table C-4: Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 04 September 2015 RESON Seabat 7125 SV on the *M/V Atlantic Surveyor*

Component	Multibeam files (pairs)		Result
Pitch	asmba15247.d22	asmba15247.d23	+1.02°
Roll	asmba15247.d22	asmba15247.d23	+0.268°
Heading	asmba15247.d24	asmba15247.d25	+0.8°

Table C-5: Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 23-24 September 2015 RESON Seabat 7125 SV on the *M/V Atlantic Surveyor*

Component	Multibeam files		Result
Pitch	asmba15266.d10	asmba15266.d11	+1.02°
Roll	asmba15267.d03	asmba15267.d04	+0.268°
Heading	asmba15267.d01	asmba15267.d04	+0.8°

After the installation of the RESON Seabat 8101 ER multibeam sonar on the *M/V Atlantic Surveyor*, roll, pitch, and heading biases were determined on 01 November 2015 (JD 305). The verification results are presented in Table C-6.

Table C-6: Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) – 01 November 2015 RESON Seabat 8101 ER on the *M/V Atlantic Surveyor*

Component	Multibeam Files		Bias
Pitch	asmba15305.d25	asmba15305.d26	+0.50°
Roll	asmba15305.d31	asmba15305.d32	+0.48°
Heading	asmba15305.d29	asmba15305.d30	+0.70°

C.2.3 Multibeam Accuracy

During the September 2015 SAT of the *M/V Atlantic Surveyor*, a small survey was run to analyze multibeam accuracies with the RESON Seabat 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 station, 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.

During the November 2015 SAT of the RESON Seabat 8101 ER onboard the *M/V Atlantic Surveyor*, a small survey was run to analyze multibeam accuracies with the RESON Seabat 8101 ER, as well as to compare against the RESON Seabat 7125 SV data previously collected (see Appendix II for details). The survey was run in the vicinity of a 1.2 meter object located in 29° 26.3937'N 093° 33.7915'W within the H12728 survey area. All depths were corrected for predicted tides and zoning using the Calcasieu Pass, LA tide station, 8768094. The Class 1 cutoff angle was set to 5° and the Class 2 cutoff angle was set to 60°. 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 and Class 1 crosslines were created and analyzed. In addition a one-meter CUBE surface of the RESON Seabat 8101 ER data was generated of all of the small survey data and compared to the two-meter CUBE surface of data previously collected with the RESON Seabat 7125 SV sonar.

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

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 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-raytraced. 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 were 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 8768094 Calcasieu Pass, LA was specified in the OPR-K371-KR-15 Project Instructions to be used as the source for water level correctors for these surveys. Included with the Project Instructions was a Statement of Work for the Tides and Water Levels (11/05/2014 HY). 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, as comma delimited text files (.csv), from the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) Tides &

Currents website. Predicted tides 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).

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 associated water level files. The Tide Zone Parameter file contains time offset and range ratio information for each of the tide zones within the survey area. These values were obtained from NOAA and are listed in Table C-7. Leidos did not modify any of these parameters. Once the *.tzp file was generated it was used to create water level files. These files were created based on the data input from the downloaded predicted or verified tide data. **SABER** outputs the water level files by zone with a file extension corresponding to the type of data (predicted or verified). For example, WGM72.ov is a water level file for Zone WGM72 which includes observed 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 correctors and applied the new correctors. 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 CO-OPS. Leidos is not required to have a final tide note from CO-OPS for OPR-K371-KR-15.

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 was used to create 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 (K371KR2015CORP.zdf), which Leidos received with the Statement of Work for the Tides and Water Levels (11/05/2014 HY).

C.4.1 Final Tide Note

All surveys were contained within preliminary water level zones WGM72, WGM81, WGM87, WGM88, WGM400, WGM401, WGM407 and WGM408 (Figure C-7) which are referenced to NOAA tide stations 8768094 Calcasieu Pass, LA. The NOAA provided zoning parameters are presented in Table C-7.

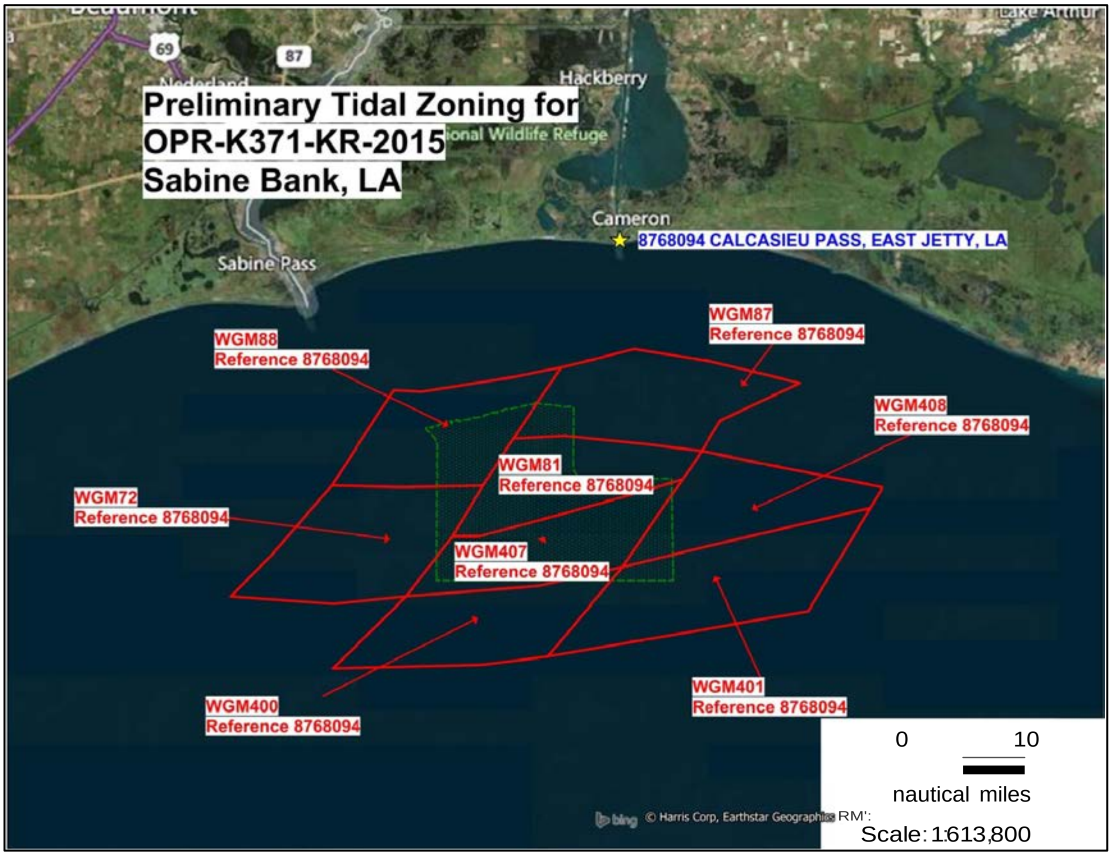

Figure C-7: Tide Zones for Station 8768094 Covering Survey Areas H12727, H12728, H12729, and H12730

Table C-7: Preliminary Tide Zone Parameters

Zone	Time Corrector (minutes)	Range Ratio	Reference Station
WGM72	+30	X1.19	8768094
WGM81	+24	X1.24	8768094
WGM88	+24	X1.30	8768094
WGM87	+18	X1.30	8768094
WGM407	+24	X1.17	8768094

Zone	Time Corrector (minutes)	Range Ratio	Reference Station
WGM400	+30	X1.11	8768094
WGM401	+24	X1.11	8768094
WGM408	+24	X1.17	8768094

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 changes 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 tide station 8768094 Calcasieu Pass, LA.

For the zone junction analysis, observed verified water levels from 22 September 2015 (JD 265) through 20 December 2015 (JD 354) were entered into a spreadsheet and the differences between adjacent zones are summarized in Table C-8.

Table C-8: 2015 Differences in Water Level Correctors between Adjacent Zones Using Zoning Parameters for Tide Station 8768094

Zone Boundary	Minimum Difference	Maximum Difference	Average Difference	Standard Deviation
WGM87 - WGM88	-0.249	0.195	0.000	0.019
WGM81 - WGM88	-0.073	0.018	-0.035	0.013
WGM81 - WGM87	-0.244	0.188	-0.035	0.023
WGM81 - WGM407	-0.021	0.086	0.041	0.015
WGM81 - WGM408	-0.021	0.086	0.041	0.015
WGM72 - WGM88	-0.285	0.138	-0.065	0.030
WGM72 - WGM407	-0.159	0.245	0.012	0.018
WGM408 - WGM407	0.000	0.000	0.000	0.000
WGM401 - WGM408	-0.073	0.018	-0.035	0.013
WGM400 - WGM407	-0.224	0.164	-0.035	0.021
WGM400 - WGM401	-0.166	0.214	0.000	0.016

As a result, the NOAA preliminary zone boundaries and zoning parameters for tide station 8768094 Calcasieu Pass, LA were accepted as final and applied to all multibeam data.

D. APPROVAL SHEET

12 February 2016

LETTER OF APPROVAL

REGISTRY NUMBER: H12727, H12728, H12729 and H12730

Field operations and data processing contributing to the accomplishment of these surveys, H12727, H12728, H12729 and H12730, 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-K371-KR-15, Sabine, LA, 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 Surveys Specifications and 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
H12727 Descriptive Report (H12727.pdf)	12 February 2016
OPR-K371-KR-15_Coast Pilot Review Report.pdf	12 February 2016

Paul L. Donaldson

Digitally signed by Paul L. Donaldson
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Paul L. Donaldson
Chief Hydrographer
Leidos
12 February 2016