U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey *Multibeam and Sidescan Sonar*

Project No. *OPR-D302-KR-10*

Time Frame: *16 November 2010 – Ongoing*

LOCALITY

State *Virginia*

General Locality *Atlantic Ocean*

2010 - 2011

CHIEF OF PARTY

Deborah M. Smith
Science Applications International Corporation

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DATE____________________________________

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REGISTRY No
HYDROGRAPHIC TITLE SHEET	**H12160** **H12161**

State	Virginia
General Locality	Atlantic Ocean
Sub Locality	11 NM East of Metompkin Island (H12160);18 NM East of Metompkin Island (H12161)
Scale	1:20,000
Date of Survey	16 November 2010 - Ongoing
Instructions Dated	27 April 2010
Project No.	OPR-D302-KR-10
Vessel	*M/V Atlantic Surveyor* D582365
Chief of Party	Deborah M. Smith
Surveyed by	Alex Bernier, Jediah Bishop, Dan Burgo, Gary Davis, Paul Donaldson, Chuck Holloway, Jason Infantino, Colette LeBeau, Rick Nadeau, Katie Offerman, Gary Parker, Evan Robertson, Eva Rosendale, Andrew Seaman, Deborah Smith, Bridget Williams
Soundings by echosounder	Multibeam RESON SEABAT 8101 ER
Verification by	
Soundings in	Meters
Soundings at	MLLW

REMARKS:

Contract:	DG133C-08-CQ-0003
Contractor:	Science Applications International Corporation 221 Third Street; Newport, RI 02840 USA
Subcontractors:	N/A
Times:	All times are recorded in UTC
UTM Zone:	Zone 18 North
Purpose:	To provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area: Sheet 1 (H12160), and Sheet 2 (H12161) in the Atlantic Ocean, Coast of Virginia.

Table of Contents *Page*

List of Tables *Page*

List of Figures *Page*

ACRONYMS

Acronym	Definition
AHB	**A**tlantic **H**ydrographic **B**ranch
ASCII	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange
BAG	**B**athymetric **A**ttributed **G**rid
CI	**C**onfidence **I**nterval
CMG	**C**ourse **M**ade **G**ood
CTD	**C**onductivity, **T**emperature, **D**epth profiler
CUBE	**C**ombined **U**ncertainty and **B**athymetric **E**stimator
DAPR	**D**ata **A**cquisition and **P**rocessing **R**eport
DGPS	**D**ifferential **G**lobal **P**ositioning **S**ystem
DPC	**D**ata **P**rocessing **C**enter
DR	**D**escriptive **R**eport
ECDIS	**E**lectronic **C**hart **D**isplay and **I**nformation **S**ystem
EPF	**E**rror **P**arameters **F**ile
GPS	**G**lobal **P**ositioning **S**ystem
GSF	**G**eneric **S**ensor **F**ormat
HDCS	**H**ydrographic **D**ata **C**leaning **S**ystem
HSSD	NOS **H**ydrographic **S**urveys **S**pecifications and **D**eliverables
Hz	**H**ert**z**
IHO	**I**nternational **H**ydrographic **O**rganization
IMU	**I**nertial **M**easurement **U**nit
ISO	**I**nternational **O**rganization for **S**tandardization
ISS-2000	**I**ntegrated **S**urvey **S**ystem 2000
ISSC	**I**ntegrated **S**urvey **S**ystem **C**omputer
JD	**J**ulian **D**ay
kHz	**K**ilo**h**ert**z**
kW	**K**ilo**w**att
MVE	**M**ulti-**V**iew **E**ditor
MVP	**M**oving **V**essel **P**rofiler
NAVOCEANO	**NAV**al **OCEAN**ographic **O**ffice
NAS	**N**etwork **A**ttached **S**torage
NMEA	**N**ational **M**arine **E**lectronics **A**ssociation
NOAA	**N**ational **O**ceanic and **A**tmospheric **A**dministration
NOS	**N**ational **O**cean **S**ervice
ONSWG	**O**pen **N**avigation **S**urface **W**orking **G**roup
PFM	**P**ure **F**ile **M**agic
POS/MV	**P**osition **O**rientation **S**ystem/**M**arine **V**essels
QA	**Q**uality **A**ssurance
QC	**Q**uality **C**ontrol
RI	**R**hode **I**sland
RPM	**R**evolutions **P**er **M**inute
SABER	**S**urvey **A**nalysis and area **B**ased **E**dito**R**
SAIC	**S**cience **A**pplications **I**nternational **C**orporation
SAT	**S**ea **A**cceptance **T**ests, or **S**wath **A**lignment **T**ool

SSP	**S**ound **S**peed **P**rofile
SV&P	**S**ound **V**elocity and **P**ressure Sensor
TPE	**T**otal **P**ropagated **E**rror
TPU	**T**otal **P**ropagated **U**ncertainty
UPS	**U**ninterruptible **P**ower **S**upply
UTC	**C**oordinated **U**niversal **T**ime
XML	e**X**tensible **M**arkup **L**anguage
XTF	e**X**tended **T**riton **F**ormat

PREFACE

This Data Acquisition and Processing Report (DAPR) applies to hydrographic sheets H12160 and H12161. Survey data were collected on H12161 in November and December 2010. Data collection will continue on H12160 in 2011 after delivery of this DAPR and the Descriptive Report (DR) for H12161. Therefore this DAPR refers to the data collection and processing that took place on data collected in 2010, up to the date of this report. Any variations that may occur subsequent to the delivery of this DAPR will be addressed in the appropriate sections of the DR for sheet H12160.

For the surveys of H12160 and H12161, no vertical or horizontal control points were established, recovered, or occupied. Therefore, a Horizontal and Vertical Control Report is not required for these sheets, and will not be submitted with the final delivery of this project.

Data collection and processing was performed according to the April 2010 version of the "*NOS Hydrographic Surveys Specifications and Deliverables*" (HSSD). Additional project specific clarifications and guidance are referenced in the supplemental correspondence email dated 03 May 2010, located in Appendix V of the Descriptive Report for H12161.

A. EQUIPMENT

A.1 DATA ACQUISITION

Central to Science Applications International Corporation's (SAIC) survey system was the Integrated Survey System Computer (ISSC). The ISSC consisted of a dual processor computer with the Windows XP (Service Pack 2) operating system, which ran SAIC's 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 multibeam and navigation data. An Applanix Position Orientation System/Marine Vessels (POS/MV) Inertial Measurement Unit (IMU) with Version 4 firmware was used to provide positioning, heave, and vessel motion data during these surveys. Klein 3000 sidescan sonar data were acquired using Klein's **SonarPro** software running on a computer with the Windows XP (Service Pack 2) operating system.

A.2 DATA PROCESSING

Data were stored on a Network Attached Storage (NAS) system that all computers were able to access. Post-acquisition multibeam and sidescan data processing was performed both on-board the survey vessel and in the Newport, RI, Data Processing Center (DPC). Multibeam data were processed on computers with the Linux operating system, which ran SAIC's **SABER** (Survey Analysis and Area Based EditoR) software. Sidescan sonar data were reviewed for bottom tracking, data quality, and contact generation utilizing Triton's **Isis** software on computers with the Windows XP (Service Pack 2) operating system. Subsequently, within **SABER**, sidescan mosaics were created and sidescan contacts were correlated with multibeam data.

A.3 THE SURVEY VESSEL

The platform used for all data collection was the *M/V Atlantic Surveyor* (Figure A-1). The vessel 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. Table A-1 presents the vessel characteristics for the *M/V Atlantic Surveyor*.

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

The sidescan winch, three 20-foot International Organization for Standardization (ISO) containers and a 50 kW generator were secured on the aft deck. The first container was used as the real-time survey data collection office, the second container was used for the data processing office, and the third container was used for spares storage, maintenance, and repairs. The generator provided dedicated power to the sidescan 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 8101 ER transducer was hull-mounted approximately amidships, port of the vessel’s keel. A Brook Ocean Technologies Moving Vessel Profiler 30 (MVP-30) was mounted to the starboard stern quarter. Configuration parameters, offsets, and installation diagrams are included in Section C of this report.

A.4 SINGLEBEAM SYSTEMS AND OPERATIONS

SAIC did not use singlebeam sonar on this survey.

A.5 LIDAR SYSTEMS AND OPERATIONS

SAIC did not use lidar systems on this survey.

A.6 MULTIBEAM SYSTEMS AND OPERATIONS

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

- Windows XP workstation (ISSC) for data acquisition, system control, survey planning, survey operations, and real-time Quality Control (QC).
- RESON SeaBat 8101 multibeam system. This system was sent to the manufacturer for an annual evaluation and compliance test in March 2011, and passed all tests, burn in, and source level measurements. A copy of the RESON 8101 report is included in Figure A-2.

RESON SeaBat 8101 ER		
Hardware	**Serial Number**	**Firmware Version 2010**
8101 Dry End	13819	2.09-E34D
8101 ER Wet End	099707	1.08-C215

RESON

The RESON Group

March 8, 2011

To: Michael Cole

Your RESON 8101 System (Sonar Head: 099707 & Processor SN: 13819) has passed our testing, burn-in, and source level measurement. As a result of the testing and evaluation on your RESON 8101, I deem your 8101 fit for service.

Sincerely,

Kelly Wright

Kelly Wright
Service Supervisor
RESON Inc.
kelly.wright@reson.com

RESON Inc., 100 Lopez Road, Goleta, CA 93117 TEL: +805 964 6260 FAX: +805 964 7537
www.reson.com

Figure A-2. Reson 8101 March 2011 Evaluation and Compliance Test Report.

- POS/MV 320 Position and Orientation System Version 4 with a Trimble ProBeacon Differential Receiver (primary positioning sensor)

POS/MV 320	
System	**Version/Model/SN**
MV-320	Ver4
SERIAL NUMBER	S/N2575
HARDWARE	HW2.9-7
SOFTWARE	SW03.42-May28/07
ICD	ICD03.25
OPERATING SYSTEM	OS425B14
IMU TYPE	IMU2
PRIMARY GPS TYPE	PGPS13
SECONDARY GPS TYPE	SGPS13
DMI TYPE	DMI0
GIMBAL TYPE	GIM0
OPTION 1	THV-0

- Trimble 7400 GPS Receiver with a Trimble ProBeacon Differential Receiver (secondary positioning sensor)
- MVP 30 Moving Vessel Profiler with interchangeable Applied Microsystems Sound Velocity and Pressure (SV&P) Smart Sensors and a Notebook computer to interface with the ISSC and the deck control unit

MVP 30	
System	**Version/Model/SN**
MVP	30
Software	2.430
SV&P Sensors	4880 4523 5332 5454 5455

- Monarch shaft RPM sensors
- Notebook computer for maintaining daily navigation and operation logs
- Uninterrupted power supplies (UPS) for protection of the entire system

The RESON SeaBat 8101 ER is a 240 kilohertz (kHz) system with 101 beams. Beams are 1.5 degrees along track and 1.5 degrees across track with a 150 degree swath (75 degrees per side). Range scale and ping rates are user selectable. The ping rate was set to a maximum of 40 pings per second and was regulated by the range scale selected.

The multibeam range scale was selected by the operator to yield the highest ping rate while maintaining a 120 degree usable swath (60 degrees per side). The range scale was selected based on water depth and was maintained at or below a range scale of 50 meters. The maximum 50-meter range scale or less was used in order to meet the requirement that 95% of all nodes of the final depth surface are populated with at least 5 soundings, Section 5.2.2.2 of the April 2010 HSSD, while maintaining an efficient survey speed. To meet this requirement, the survey speed was typically maintained below 5.7 knots while using a maximum multibeam range scale of 50 meters to ensure at least 95% of all nodes on the surface are populated with at least five soundings. While operating at multibeam range scales below 50 meters, the maximum survey speed was constrained by the sidescan range scale settings, and is discussed in greater detail in the Sidescan Sonar Systems and Operations Section (A.7) of this report.

SAIC maintains the ability to decrease the usable multibeam swath width if necessary, however, if this ability is exercised, the multibeam swath width is always maintained above 90 degrees (45 degrees per side).

All item investigation data were collected at slower survey speeds, generally four knots or less, and at the maximum achievable ping rate for the selected RESON 8101 range. As a result, all significant features meet the object detection requirements as defined in Section 5.2.2.1 of the April 2010 HSSD, unless otherwise specified in a sheet's Descriptive Report.

The resultant achievable multibeam bottom coverage was controlled by the set survey line spacing. The line spacing was determined based on the sidescan range scales used for various water depths within the survey areas. In deeper waters, greater than approximately 18 meters (60 feet), survey line spacing was 65 meters and a sidescan range setting of 75 meters was used. In shallower waters, less than approximately 18 meters (60 feet), survey line spacing was 40 meters with a sidescan range setting of 50 meters used.

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 that a copy of all real time data files were logged to separate hard drives during the survey operations. File names were changed at the end of each line and an archiving routine was run to copy all files to an on-board NAS.

SAIC's naming convention of multibeam Generic Sensor Format (GSF) data files has been established to provide specific identification of the survey vessel and/or sonar system used, the year and Julian Day that the data file was collected, and the sequential data file number of the given JD. For example, multibeam file "asmba10307.d14"; "as" refers to the survey vessel *M/V Atlantic Surveyor*, "mba" refers to a multibeam file, "10307" refers to JD 307 of the year 2010, and ".d14" identifies this multibeam file as the fourteenth consecutive file collected on JD 307 of the year 2010.

In cases where multiple multibeam sonar systems were used on the same survey vessel during the same project or task order, the first two characters of the multibeam GSF naming convention, were replaced with identifiers of the multibeam sonar system. For example, in multibeam file "81mba10322.d24", "81" refers to the Reson 8101 sonar system in use, "mba" identifies the data as multibeam data, "10322" refers to JD 322 of the year 2010, and ".d24" identifies this file as the twenty-fourth consecutive file collected on JD 322 of the year 2010.

As previously stated, multibeam file names were manually changed within the **ISS-2000** system at the end of each survey line. This protocol provided the ability to easily associate each consecutive multibeam GSF file number ".dXX" with a specific survey line. Due to software restrictions within **ISS-2000** and **SABER** there is a limitation of 99 consecutive ".dXX" files per JD. Therefore, when survey operations would potentially result in more than 99 survey lines per day, such as holiday fill and/or item investigation, groups of multiple survey lines of the same type run consecutively were grouped together within the same multibeam GSF file. In all cases, main scheme and crossline data were collected in separate multibeam GSF files.

If file names were not manually changed between survey lines, the multibeam GSF file was typically later split during post processing using the **SABER** command line program **gsfsplit**. This program provided the ability to split multibeam files so that each survey line, originally collected in one multibeam file, resulted in being stored in its entirety, in its own multibeam GSF file.

When a multibeam file needed to be split, a copy of the original multibeam file was made, and the **gsfsplit** program was then run on the copy of the original file. The **gsfsplit** program splits the multibeam 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. Typically split files were given high sequential file number extensions, such as ".d99". The sequential file number extension consecutively counted backwards, for each new file created, based on the amount of splits needed per JD (i.e. ".d99, .d98, .d97, etc). These high file number extensions, working backwards from file ".d99", were chosen based on the software limitation of 99 ".dXX" file numbers per day, as well as to ensure that there would never be an occurrence of more than one multibeam file with the same sequential file number extension in the same JD of survey. Once the file split process was complete, and newly created files were assigned their ".dXX" sequential file number extensions, the new file containing only the first survey line collected within the original multibeam file that had been split, was re-named to have the original ".dXX" sequential file number extension of the original multibeam file.

Multibeam file lists were updated to include the split files placed in chronological order. Any file splits that occurred were documented in the Multibeam Processing Log spreadsheet provided in Separates I of each sheet's Descriptive Report.

At the start of each JD all raw real-time data files from the previous JD were backed-up to digital magnetic tape from the hard drives of the ISSC machine. The data which were auto archived to the NAS were used for processing. All processed data were backed-up to an external hard drive and digital magnetic tape approximately every one to two days. The external hard drive and copies of the digital magnetic tape back-ups were then shipped to SAIC's Data Processing Center (DPC) in Newport, RI for final processing and archiving during port calls (approximately every 10 to 12 days).

SAIC continuously logged multibeam data throughout survey operations and did not stop and re-start logging at the completion and/or beginning of survey lines. Therefore, data were collected and logged during all turns and transits between survey lines. SAIC utilized a ping flag within the multibeam GSF file to represent "offline" data. "Online" multibeam data refers to the bathymetry data within a multibeam GSF file which were used for generating the Combined Uncertainty and Bathymetric Estimator (CUBE) surface. "Offline" multibeam data refers to the bathymetry data within a multibeam GSF file which were not used for generating the CUBE 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 are logged and contained in the "Watchstander Logs" and "Sidescan Review Log" delivered in Separates I of each sheet's Descriptive Report.

Lead line comparisons were conducted for Quality Assurance (QA) and to provide confidence checks of the RESON 8101 multibeam system. A lead line was used in accordance with Section 5.2.3.1 of the April 2010 HSSD, periodic lead line comparisons were made during port calls (approximately every 10 - 12 survey days).

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

- The draft of the survey vessel is measured immediately prior to the beginning of the comparison, and this observed static draft value is entered into the **ISS-2000** real-time parameters for the RESON 8101 (see Section C.2.1 of this report for a detailed description of how static draft is measured).
- Correctors to the multibeam data, such real-time tides, are disabled in the **ISS-2000** system.
- A new sound speed profile is taken and applied to the multibeam data.
- A digital watch is synchronized to the time of the **ISS-2000** data acquisition system in order to accurately record the time for each lead line depth observation.
- A spreadsheet (Figure A-3) is filled out which includes the Julian Day, date, vessel draft value entered into the real-time acquisition system, the multibeam data file(s) being logged for use in the comparison, and the sound speed profile which is applied to the multibeam data.
- The observed time and depth of each lead line measurement is entered into the spreadsheet.
- The recorded multibeam depth measurements at the time of the measurements are then entered into the spreadsheet.

Lead line depth measurements are made using a mushroom anchor affixed to a line and a tape measure (millimeter resolution). Lead line depth measurements are taken by placing a 0.02 meter square metal bar on the deck (at approximately amidships even with the RESON 8101 ER transducer) so that it extends out far enough to allow a direct measurement to the seafloor. The distance between the top of the metal bar and the seafloor is measured. At least ten separate depth measurements and corresponding times are recorded. This procedure is done for both the port and starboard sides of the survey vessel.

Once all lead line measurements and times have been recorded in the lead line spreadsheet, SAIC's **ExamGSF** program is used to view the data within the multibeam GSF file which was logged at the times of observed lead line measurements. The depth value recorded in the multibeam file at the time of the 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 RESON 8101 multibeam system. Results of the lead line comparison were reviewed and if any differences or discrepancies were found, further investigation was conducted. Lead line results are included with the survey data in Section I of the Separates of each sheet's Descriptive Report.

LEADLINE COMPARISON						
DAY	318	DRAFT ENTERED IN COMPUTER =	2.26			FILES
DATE	11/14/10	DRAFT ON HULL =	2.26		port	81mba10318.d06
		SQUAT DEPTH CORRECTOR LEFT IN =	0.00		stbd	81mba10318.d06
		DRAFT CORRECTOR =	0.00		SVP	81svt10318_d01.svp
		PORT DECK TO WATER SURFACE =	1.05			
		STBD DECK TO WATER SURFACE =	1.04	0.00	<=TIDE CORRECTOR LEFT IN	

cast #	time taken port UTC	port deck to bottom meters	port cast depth meters	multibeam depth port (3.3m)	corrected multibeam depth port	time taken starboard UTC	stbd deck to bottom meters	stbd cast depth meters	multibeam depth starboard (4.4m)	corrected multibeam depth stbd	port difference meters	starboard difference meters
1	20:32:00	5.24	4.19	4.19	4.19	20:25:35	4.91	3.87	3.89	3.89	0.000	-0.020
2	20:32:05	5.23	4.18	4.18	4.18	20:25:40	4.90	3.86	3.88	3.88	0.000	-0.020
3	20:32:10	5.23	4.18	4.15	4.15	20:25:45	4.91	3.87	3.88	3.88	0.030	-0.010
4	20:32:15	5.22	4.17	4.18	4.18	20:25:50	4.90	3.86	3.88	3.88	-0.010	-0.020
5	20:32:20	5.21	4.16	4.16	4.16	20:25:55	4.90	3.86	3.87	3.87	0.000	-0.010
6	20:32:25	5.25	4.20	4.18	4.18	20:26:00	4.89	3.85	3.88	3.88	0.020	-0.030
7	20:32:30	5.23	4.18	4.12	4.12	20:26:05	4.90	3.86	3.88	3.88	0.060	-0.020
8	20:32:35	5.24	4.19	4.19	4.19	20:26:10	4.92	3.88	3.88	3.88	0.000	0.000
9	20:32:40	5.24	4.19	4.20	4.20	20:27:55	4.92	3.88	3.87	3.87	-0.010	0.010
10	20:32:45	5.23	4.18	4.18	4.18	20:27:55	4.92	3.88	3.87	3.87	0.000	0.010
										Mean	0.009	-0.011
										StdDev	0.022	0.014

Figure A-3. *M/V Atlantic Surveyor* Example Lead Line Spreadsheet

A.7 SIDESCAN SONAR SYSTEMS AND OPERATIONS

These survey operations were conducted at set line spacing optimized to achieve 200% sidescan sonar coverage.

The sidescan system used for these surveys included each of the following unless otherwise specified:

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

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

The sidescan sonar ping rate is automatically set by the transceiver based on the range scale setting selected by the user. At a range scale of 50 meters, the ping rate is 15 hertz (Hz) and at a range scale of 75 meters, the ping rate is 10 Hz. Based on these ping rates, maximum survey speeds were established for each range scale setting to ensure that there were a minimum of three pings per meter in the along-track direction, in accordance with Section 6.2 of the April 2010 HSSD. The maximum allowable survey speeds were 9.7 knots at the 50-meter range and 6.4 knots at the 75-meter range, therefore the survey speeds were typically less than 8.5 knots and 6 knots respectively. As discussed in Section A.6 the survey vessel speed was also constrained by the RESON 8101 and was maintained at a level so that the multibeam object detection coverage requirements (Section 5.2.2.1) and the multibeam set line spacing coverage requirements (Section 5.2.2.3) of the April 2010 HSSD were also met.

During survey operations, 16-Bit digital data from the Klein 3000 processor were acquired, displayed, and logged by the Klein 3000 Windows XP computer through the use of Klein's **SonarPro** software. Raw digital sidescan data from the Klein 3000 was collected in eXtended Triton Format (XTF) and maintained at full resolution, with no conversion or down sampling techniques applied. Sidescan data file names were changed automatically approximately every hour and manually at the completion of a survey line. These files were archived to the on-board NAS for initial processing and quality control review at the completion of each survey line. At the beginning of each survey day the raw XTF sidescan data files from the previous day were backed up on digital magnetic tapes and external hard drives which were shipped to the DPC in Newport, RI, during port calls (approximately every 10 to 12 days).

SAIC's naming convention of sidescan XTF data files has been established through the structure of Klein's **SonarPro** software to provide specific identification of the survey vessel and/or sonar system used, the JD that the data file was collected, the calendar date, and the specific time that the file was created. For example, sidescan file "as307_101103203500.xtf"; "as" refers to the survey vessel *M/V Atlantic Surveyor*, "307" refers to JD 307, the next six digits after the underscore refer to the calendar date (yymmdd) the file was created (in this case "101103" is November 3rd of the year 2010), and next four digits refer to the time (hhmm) the file was created and logging began (in this case 2035) and the last two digits are an sequential number for a file created within the same minute. For example if you were start logging, stop logging and restart logging all within the same minute the last two digits for the first file will be 00 and the second file will be 01.

In cases where multiple multibeam sonar systems were used on the same survey vessel during the same project or task order, the first two characters of the sidescan XTF naming convention, which represented the survey vessel, were replaced with identifiers of the multibeam sonar system. This allows for easy cross reference with the multibeam files which follow the same naming logic. For example, in sidescan file "81322_101118144000.xtf", "81" refers to the Reson 8101 sonar system in use on the survey vessel *M/V Atlantic Surveyor;* all other remaining sixteen characters of the naming convention remain representing the descriptions stated previously.

As done with multibeam bathymetry data, SAIC continuously logged sidescan 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.

SAIC utilizes “time-window” files to distinguish between times of “online” and “offline” sidescan data. “Online” sidescan data refers to the data logged within a sidescan XTF file which were used for generating either the 1_100% or 2_100% coverage mosaic. “Offline” sidescan data refers to the data logged within a sidescan XTF file which were not used for generating either the 1_100% or 2_100% coverage mosaic.

Online data were represented in the time-window file by a date and time stamp which represented the start and end times of online data for each individual survey line. Each date and time stamp was associated to a specific survey line represented by the survey line number in the time-window file. Offline times of sidescan data were excluded from the time-window file.

In order to correlate individual sidescan files to their associated survey lines, SAIC manually changed sidescan file names after the completion of each survey line, typically midway in the turn to the next line. Information regarding the start and end of “online” data for each survey line were logged and contained in the “Watchstander Logs” and “Sidescan Review Log” delivered in Separates I of each sheet’s Descriptive Report.

Towfish positioning was provided by **ISS-2000** through a program called Catenary that used a Payout and Towfish Depth method (Figure A-4) 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. The towfish position was then calculated from the tow point position using the measured cable out (received by **ISS-2000** from the cable payout meter), the towfish pressure depth (sent via a serial interface from the Klein 3000 computer to **ISS-2000**), and the Course Made Good (CMG) of the vessel. The calculated towfish position was sent to the Klein 3000 data collection computer via the TowfishNav program module of **ISS-2000**, at least once per second in the form of a GGA (NMEA-183, National Marine Electronics Association, Global Positioning System Fix Data String) message where it was merged with the sonar data file. Cable adjustments were made using a remote winch controller inside the real-time survey acquisition ISO container in order to maintain acceptable towfish altitudes and sonar record quality. Changes to the amount of cable out were automatically saved to the **ISS-2000** message and payout files.

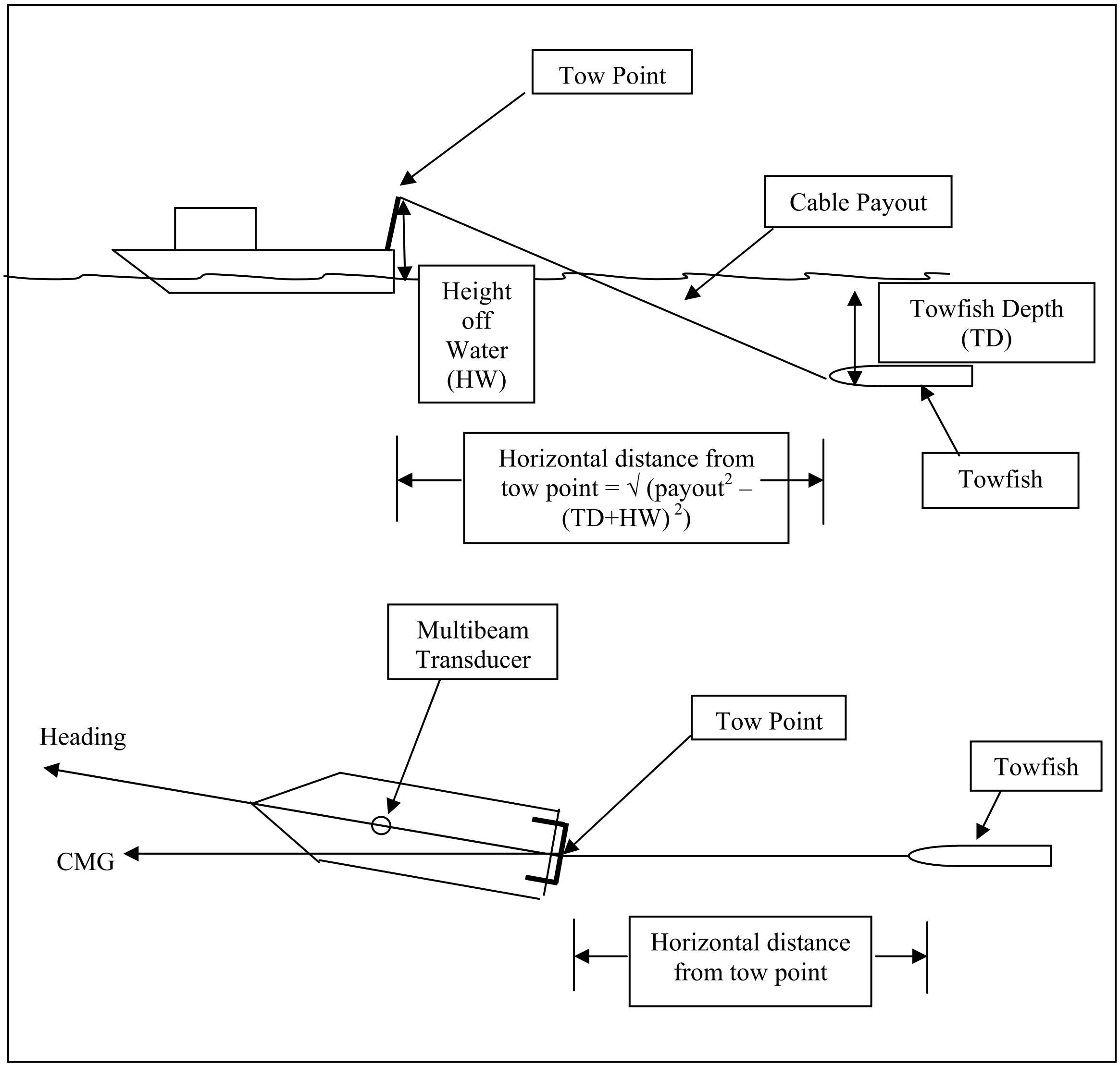

Figure A-4. Geometry of Sidescan Towfish Position Calculations Using the Payout and Depth Method.

Towfish altitude was maintained between 8% and 20% of the range scale (4-10 meters at 50-meter range; 6-15 meters at 75-meter range), in accordance with Section 6.2.3 of the April 2010 HSSD, when conditions permitted. For personnel, vessel, and equipment safety, data were occasionally collected at towfish altitudes outside the 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 the 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 constantly made during data collection to verify the quality of the sonar data across the full sonar record range. These periodic confidence checks were made once or more per survey line when possible to do so, however they were always made at least once per each survey day in accordance with Section 6.3.1 of the April 2010 HSSD. When the towfish altitude was outside 8% to 20% of the range, the amount and frequency of confidence checks was increased in order to verify and ensure the quality of the sonar data across the full sonar range.

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

A.8 SOUND SPEED PROFILES

A Brooke Ocean Technology Moving Vessel Profiler (MVP) with an Applied Microsystems SV&P Smart Sensor was used to collect sound speed profile (SSP) data. SSP data were obtained at intervals frequent enough to reduce sound speed errors in the multibeam data. The frequency of SSP casts was based on observed sound speed changes from the surface sound speed measurements at the towed SV&P sensor, observed sound speed changes from previously collected profiles, and time elapsed since the last applied SSP cast. 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 a line where this was done, the SSP cast frequency and locations were modified accordingly for subsequent lines.

In accordance with Section 5.2.3.3 of the April 2010 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. Often throughout the duration of the survey, SSP comparison confidence checks and multibeam lead line confidence checks were performed outside the boundaries of the survey area. This was typically done to utilize areas of greater depth for SSP comparison confidence checks and areas which provided both a flat bottom and sheltered sea state for multibeam lead line confidence checks. The SSP casts taken during confidence checks were applied to the multibeam files currently being logged in **ISS-2000** at that time, in order for SAIC's processing and analysis of the comparisons to be conducted and properly logged. In some rare cases, a multibeam file which was logged during the time of a confidence check that occurred beyond the boundaries of the survey area may have been used to collect survey data. In these cases, the SSP casts taken for use in the confidence check were only applied to "offline" data within the multibeam file, and a new SSP cast was acquired in the immediate area of the survey site and applied to the multibeam file prior to the collection of any online data with said multibeam file (in accordance with the SSP specifications for multibeam operations, Section 5.2.3.3, of the April 2010 HSSD).

SAIC did not utilize a CTD (Conductivity, Temperature, Depth profiler) for collection of SSP data on sheet H12161. When SAIC utilizes a CTD for the collection of SSP data, a Seabird SBE-19 CTD is used, and the Chen-Millero equation is used to calculate sound speed values from the observed conductivity, temperature, and depth measurements.

Serial numbers and calibration dates are listed below for the Applied Microsystems SV&P Smart Sensors used on this survey. Sound speed data are included with the survey data delivered for each sheet. An SSP application log, confidence check SSP comparison cast log, and sensor calibration records are included with the survey data in Section II of the Separates for each sheet's Descriptive Report.

- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 4523, Calibration Dates: 29 October 2010. On 08 December 2010, the sensor flooded and was no longer used. Therefore a post survey calibration was not possible.
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5332, Calibration Dates: 15 March 2010, 16 February 2011 (Post-survey)
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 4880, Calibration Dates: 29 October 2010, 16 February 2011 (Post-survey)
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5454, Calibration Dates: 05 February 2010, 14 February 2011 (Post-survey)
- Applied Microsystems Ltd., SV&P Smart Sensor, Serial Number 5455, Calibration Dates: 15 March 2010, 16 February 2011 (Post-survey)

A.9 BOTTOM CHARACTERISTICS

Bottom characteristics were obtained using a WILDCO Petite Ponar Grab (model number 7128-G40) bottom sampler. The locations for acquiring bottom characteristics were evenly distributed throughout the survey area, at a distance of approximately 2000 meters. 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 on a J-Frame located amidships on the starboard side of the survey vessel. Each seabed sample was classified using characteristics to quantify texture and particle size. The nature of the seabed may in some cases be characterized as "Hard" if a bottom sample was not obtained after several attempts.

The position of each seabed sample was marked in SAIC's **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 in the message file with the unique identification number of the sample obtained. These event records in the message file included position, JD, and time along with user input for depth, the general nature of the type of seabed sample obtained, and any qualifying characteristics to quantify texture and grain size.

The bottom sample event records saved in the message files from **ISS-2000** were used to populate Bottom Sample Logs. These Bottom Sample Logs provided a central location for all the inputs listed above. Real-time Watchstander Logs were also updated as each bottom sample was obtained. The Real-time Watchstander Log provides a record of the time and sample number, as well as the digital image filename(s) for each photograph taken for each individual sample obtained.

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

A.10 DATA ACQUISITION AND PROCESSING SOFTWARE

Data acquisition was carried out using SAIC's **ISS-2000** Version 4.2.0.5.0 software for Windows XP operating systems to control acquisition navigation, data time tagging, and data logging.

Survey planning, data processing and analysis were carried out using SAIC's **Survey Planning** and **SABER** Version 4.3.0.16.0 software for LINUX operating systems. SABER version 4.4.0.13.15 was used exclusively to generate the S-57 feature file.

Periodic upgrades to this software were installed both in the Newport, RI Data Processing Center and on the survey vessel. The version and installation dates of **Survey Planning** and **SABER** used during the processing and analysis of these data in SAIC's Newport DPC and on-board the survey vessel are listed in Table A-2.

Table A-2. SABER Versions and Installations Dates

Newport DPC SABER and Survey Planning Version	Date Version Installed In Newport, RI	Date Version Installed On Vessel
4.3.0.16.1	26 March 2010	26 March 2010
4.3.0.16.5	02 August 2010	05 August 2010
4.4.0.13.15	10 January 2011	N/A

SonarPro version 11.3, running on a Windows XP platform was used for sidescan data acquisition.

Isis version 6.06, running on a Windows XP platform was used for sidescan data quality review, contact identification, and contact file generation.

A.11 SHORELINE VERIFICATION

Shoreline verification was not required for this survey.

B. QUALITY CONTROL

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

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

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

- Initial swath editing of multibeam data flagging invalid pings and beams
- Application of delayed heave
- Generation of a preliminary Pure File Magic (PFM) CUBE surface
- Second review and editing of multibeam data PFM CUBE surface
- Open beam angles where appropriate to identify significant features outside the cut-off angle
- Identify significant features for investigation with additional multibeam coverage
- Turning unacceptable data “offline”
- Turning additional data “online”
- Identification and flagging of significant features
- Track plots
- Preliminary minimum sounding grids
- Crossline checks
- First review of sidescan data
- Generation of sidescan contact files
- Generation of preliminary sidescan coverage mosaics
- Identification of holidays in the sidescan coverage
- Second review of sidescan data when practical

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

- Main scheme, item, and holiday fill survey lines

- Crosslines using only near-nadir data (±5° from nadir)

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

During port calls a complete backup of all raw and processed multibeam data and sidescan data was sent to SAIC's DPC in Newport, RI. Analysis of the data at the Newport facility included the following steps:

- Generation of multibeam and sidescan track line plots
- Second review of sidescan data
- Verification of sidescan 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 prior surveys
- Generation of final CUBE PFM surface(s)
- Generation of S-57 feature file
- Comparison with existing charts
- Quality control reviews of sidescan data and contacts
- Final Coverage mosaics of sidescan sonar data
- Correlation of sidescan contacts with multibeam features
- Generation of final Bathymetric Attributed Grid(s) (BAG) and metadata products
- Final quality control of all delivered data products

Figure B-1 depicts the overall flow of SAIC's data processing routines from the acquisition of raw soundings to the final grids and deliverable data.

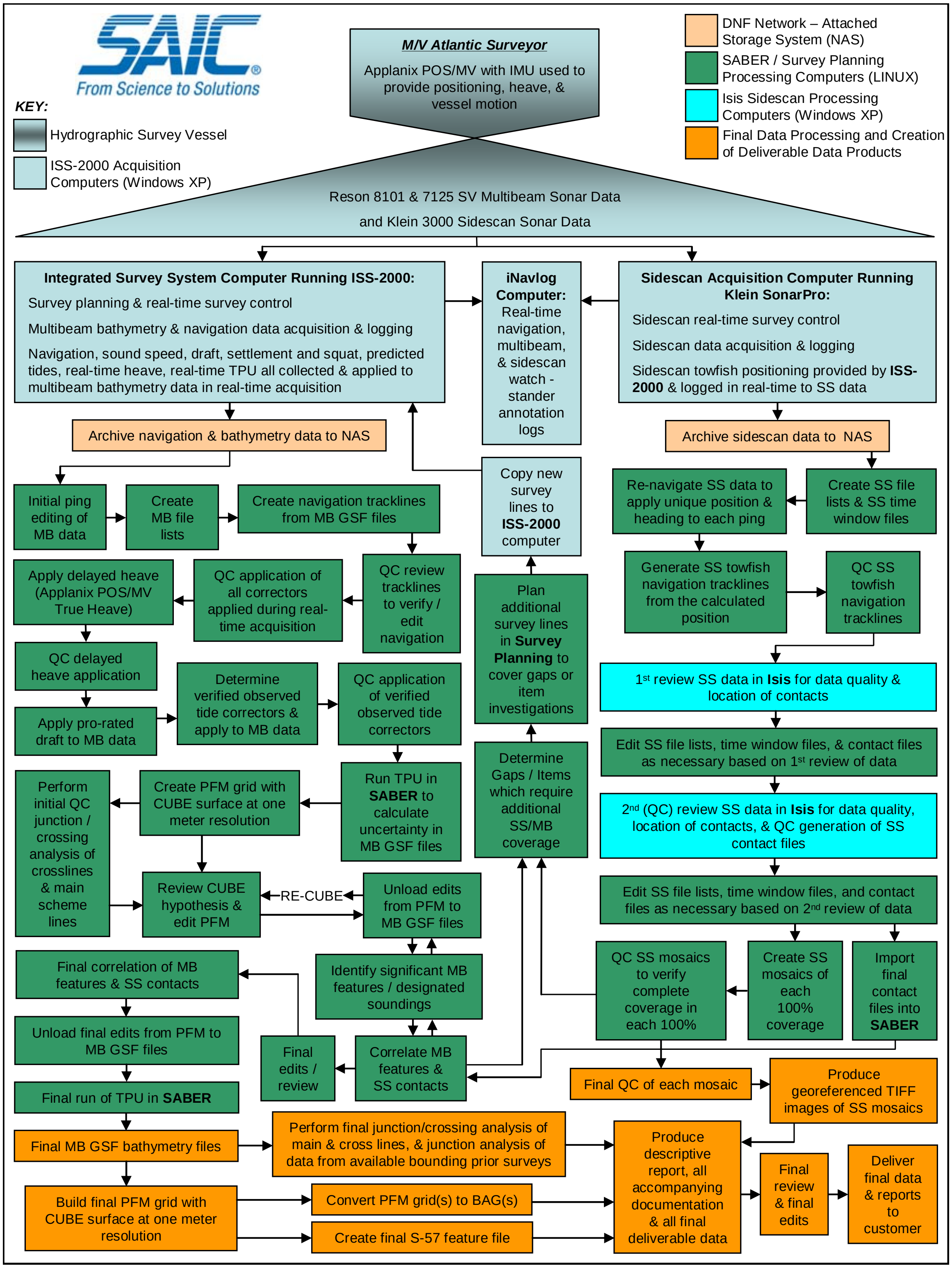

Figure B-1. SAIC Data Acquisition and Processing Flow Chart

B.1 SURVEY SYSTEM UNCERTAINTY MODEL

The TPU model that SAIC has adopted has its genesis at the Naval Oceanographic Office (NAVOCEANO), and is based on work by Rob Hare and others ("Error Budget Analysis for NAVOCEANO Hydrographic Survey Systems, Task 2 FY 01", 2001, *HSRC FY01 Task 2 Final Report*). The terminology Total Propagated Error (TPE) has been replaced by Total Propagated Uncertainty (TPU). This was adopted by the International Hydrographic Organization in Special Publication No. 44, "*IHO Standards for Hydrographic Surveys, 5th Edition, February 2008*". The fidelity of any uncertainty model is coupled to the applicability of the equations that are used to estimate each of the components that contribute to the overall uncertainty that is inherent in each sounding. SAIC's approach to quantifying the TPU is to decompose the cumulative uncertainty for each sounding into its individual components and then further decompose those into the horizontal and vertical components. The model then combines the horizontal and vertical uncertainty components to yield an estimate of the system uncertainty as a whole. This cumulative system uncertainty is the Total Propagated Uncertainty. By using this approach, SAIC can more easily incorporate future uncertainty information provided by sensor manufacturers into the model. This also allows SAIC to continuously improve the fidelity of the model as our understanding of the sensors increases or as more sophisticated sensors are added to a system.

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 cumulative TPU estimates were recorded as the Horizontal Uncertainty and Vertical Uncertainty at the 95% confidence level in the GSF file. Individual soundings that had vertical and horizontal uncertainty values above IHO Order 1a were flagged as invalid during uncertainty attribution of the GSF files.

Table B-1 and Table B-2 show the values entered in the **SABER** EPF used with the RESON 8101. 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 8101

Parameter	Value	Units
VRU Offset – X	0.34	Meters
VRU Offset – Y	0.12	Meters
VRU Offset – Z	-1.64	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

Parameter	Value	Units
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
Antenna Offset – Z	-8.02	Meters
Antenna Offset Error – X (uncertainty)	0.013	Meters
Antenna Offset Error – Y (uncertainty)	0.012	Meters
Antenna Offset Error – Z (uncertainty)	0.020	Meters
Estimated Error in Vessel Speed (uncertainty)	0.0299	Knots
GPS Latency	0.00	milliseconds
GPS Latency Error (uncertainty)	1.00	milliseconds
Horizontal Navigation Error (uncertainty)	0.75*	Meters
Vertical Navigation Error (uncertainty)	0.20*	Meters
Static Draft Error (uncertainty)	0.01	Meters
Loading Draft Error (uncertainty)	0.02	Meters
Settlement & Squat Error (uncertainty)	0.034	Meters
Predicted Tide Measurement Error (uncertainty)	0.17	Meters
Observed Tide Measurement Error (uncertainty)	0.07	Meters
Unknown Tide Measurement Error (uncertainty)	0.50	Meters
Tidal Zone Error (uncertainty)	0.10	Meters
Surface Sound Speed Error (uncertainty)	1.00	meters/second
SEP Uncertainty	0.15	Meters
SVP Measurement Error (uncertainty)	1.00	meters/second
Depth Sensor Bias	0.00	Meters
Depth Measurement Error (% error of depth) (uncertainty)	0.00	Percent
Wave Height Removal Error (uncertainty)	0.05	Meters

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

Table B-2. RESON 8101 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)	0.00	Meters
Transducer Offset Error – Y (uncertainty)	0.00	Meters
Transducer Offset Error – Z (uncertainty)	0.00	Meters
Roll Offset Error (uncertainty)	0.005	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	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, and data processing then began with the generation of track lines and the review of multibeam data files to flag erroneous data such as noise, flyers, fish, etc. The multibeam data were reviewed and edited on-board the vessel using SAIC's **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.

Once the multibeam data were reviewed and edited, delayed heave was applied to the GSF files. SAIC refers to true heave as delayed heave. The process to apply delayed heave uses the Applanix *TrueHeave*™ (.thv) files (for further detail refer to Section C.4). Next, preliminary TPU was 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. These tapes and hard drives were shipped to the DPC in Newport, RI at each port call.

Once the data were in Newport and extracted to the NAS unit for the DPC, the initial processing step was to create track lines from the multibeam data. Once created, the tracks were reviewed to confirm that no navigational errors existed and that the tracks extended to the survey limits. Verified water levels, delayed heave, and prorated static draft, were also applied to the data at this time. The final TPU for each beam was then calculated and applied to the multibeam data.

For each survey sheet, all multibeam 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 allowable uncertainty as specified in Section 5.1.3 of the April 2010 HSSD.

Two separate uncertainty surfaces are calculated by the **SABER** software, CUBE Standard Deviation and Average Total Propagated Uncertainty (Average TPU). The CUBE Standard Deviation is a measure of the general agreement between all of the soundings that contributed to the best hypothesis for each node. The 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 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. An initial review of the areas with final uncertainties exceeding IHO Order 1a revealed that most of these areas were around wrecks, obstructions, and on steep slopes where there tended to be much greater variability in the soundings that contributed to a particular node. In some cases, this uncertainty review resulted in the creation of additional features or designated soundings on reliable soundings that were shoaler than the CUBE depths by one-half the allowable uncertainty for that depth. In addition, the uncertainty review also highlighted some areas that required additional data cleaning. When all multibeam files and the PFM CUBE surface were determined to be satisfactory, the PFM's CUBE Depth Surface and the Final Uncertainty Surface were converted to BAGs for final delivery.

B.2.1 Multibeam Coverage Analysis

Multibeam coverage analysis was conducted during data processing and on the final CUBE surface to identify areas where multibeam holidays exceeded the allowable three contiguous nodes in accordance with Section 5.2.2.3 of the April 2010 HSSD. As previously stated in Section A.6, these survey operations were conducted at set line spacing optimized to achieve 200% sidescan sonar coverage; 100% multibeam coverage was not required.

The **SABER** Gapchecker utility was run on the CUBE surface to identify multibeam data holidays exceeding the allowable three contiguous nodes. In addition, the entire surface was visually scanned for holidays. While field operations were still underway, additional survey lines were run to fill any holidays that were detected. A limited number of small multibeam coverage gaps may have remained after data processing, resulting primarily from additional cleaning of noise in the outer beams caused by cavitation or schools of fish. Results of the multibeam coverage analysis are presented in Section B.2.5 of each sheet's Descriptive Report.

All grids for each survey were also examined for the number of soundings contributing to the chosen CUBE hypotheses for each node. This was done by running **SABER's** Frequency Distribution tool on the CUBE number of soundings layer. The CUBE number of soundings layer reports the number of soundings that were used to compute the best hypothesis. This analysis was done to ensure that at least 95% of all nodes contained five or more soundings, ensuring the requirements for complete multibeam coverage as specified in Section 5.2.2.2 of the April 2010 HSSD were met. A complete analysis based on the output of the Frequency Distribution tool is provided in Section B.2.5 of each sheet's Descriptive Report.

B.2.2 Junction Analysis

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

- Main scheme, item, and holiday fill survey lines (full valid swath, ±60° cutoff)
- Crosslines (Class1 data only, ±5° cutoff)

A depth difference surface was then computed in **SABER** between the CUBE Depth surfaces of the main scheme and crossline grids, and the **SABER** Junction Analysis routine was used to summarize the results of the depth difference grid. To do this the Junction Analysis routine in **SABER** used the depth difference grid to perform a statistical evaluation on depth differences between the main scheme and crossline grids. The program then reported the number and percentage of difference values that fell within evenly distributed depth difference ranges (in centimeters from zero to the maximum depth difference value).

The junction analysis was performed by subtracting a grid from a separate reference grid. For instance, if the crossline grid was subtracted from the main scheme grid (reference layer) a positive value indicates that main scheme data are deeper than the crossline data, and negative values indicates that main scheme data are shoaler than the crossline data. Each sheet's DR describes which grid layer was subtracted from the reference layer. The number count and percentage of depth difference values was 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.

The **SABER** Frequency Distribution tool was also run on the depth difference grid created for use in the junction analysis. This was used to provide an additional analysis of the accuracy of the multibeam data as well as a QC check of the junction analysis results.

Results of the junction analysis and frequency distribution analysis are presented in the DR for each survey.

B.2.3 Crossing Analysis

In addition to the junction analysis, a beam-by-beam comparison of crossline data to main scheme data was performed for each survey area. This two-step process began by finding all beam-to-beam crossings that occur between the main scheme lines and crosslines within the survey area. This was accomplished by running **SABER's** Find Crossings utility on two file lists, one containing main scheme multibeam files and one containing crossline multibeam files. The resulting file contains positional data for all crossings between the data of the two file lists and can be displayed in **SABER**. A subset of 25 crossings for each survey was then selected from the Find Crossings results by selecting crossings that were separated both temporally and spatially, and in relatively flat areas within each survey area. See Section A.6 for details of main scheme and crossline operations for each survey area.

SABER's Analyze Crossings utility was then used to calculate the various beam statistics and generate reports that comprise the complete crossing analysis. The output from **SABER's** Analyze Crossings utility contains the number of comparisons, number and percentage of comparisons that meet an operator specified criteria for acceptable depth difference, maximum difference, minimum difference, and statistics which include mean, standard deviation, and R95, for each beam-to-beam comparison. Each crossing generates two analysis reports. One report is for near-nadir beams of the main scheme line as compared to the full swath beams of the crossline, and the second is for the near-nadir beams of the crossline as compared to the full swath beams of the main scheme line. Results are presented in Separates IV of each survey's Descriptive Report.

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). SAIC is a member of the CCOM Consortium and the CUBE algorithm has been licensed to SAIC 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 of surveys H12160 and H12161, 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.

To create the bathymetric CUBE Depth Surface, there are four processing stages within the CUBE algorithm method; the Scatter Stage, the Gather Stage, the Insertion Stage, and the Extraction Stage.

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 5.2.2.1 and 5.2.2.2 of the April 2010 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 were soundings are written prior to calculation of a hypothesis. The queue is used to delay the impact of outliers on the hypothesis. Currently, the queue limit within **SABER** is 11 soundings. CUBE will not calculate a depth hypothesis for a node until all available soundings have entered the queue or there are at least 11 soundings and their associated propagated variance values in that node's queue.

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

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

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

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

This disambiguation method (Prior) 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 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 on all those data contributing to the build of the PFM layer. The CUBE algorithm adds a series of surfaces to the PFM layer, each containing a different CUBE data type, in addition to the standard non-CUBE PFM surfaces. These are:

- *CUBE Depth*, which contains the depth value from the node's best hypothesis (unless there is an over-ride).
- *CUBE Number of Hypotheses*, which shows the number of hypotheses that were generated for each node.
- *CUBE 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 H12160 and H12161 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.
- *CUBE 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.
- *CUBE Number of Soundings*, which reports the number of soundings that were input into the best 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.
- *Final Uncertainty*, this surface is populated with the greater value of the CUBE Standard Deviation and the Average TPU surfaces.

Once built, the different PFM surfaces were displayed, analyzed, and edited using **SABER**. All PFM surfaces were used throughout SAIC's 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 April 2010 HSSD were met. When all survey data were finalized, SAIC re-built a final PFM using the CUBE option. This final PFM, and all associated surfaces, were run though a final QC procedure, and it was then used in SAIC's combine CUBE/BAG approach implemented within **SABER**. Here **SABER** provided the ability to directly export the CUBE Depth surface and associated Final Uncertainty surface from the PFM to a BAG layer. This process was done through the use of the Convert PFM to BAG utility in **SABER**. This same process was also used to produce the additional non-standard BAG files requested by NOAA's Atlantic Hydrographic Branch (AHB). The BAG layer and the additional non-standard BAG files are described in the next Section B.2.5.

B.2.5 Bathymetric Attributed Grids

A Bathymetry 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 gridded data format containing gridded elevation data, a co-aligned uncertainty data grid, survey acquisition and post-processing related metadata, a node-change list, and digital file signature and certification/authentication needs.

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 SAIC has implemented a combined CUBE/BAG approach in **SABER** (see Section B.2.4 for a detailed description about the CUBE Surface). In this approach, **SABER** creates BAG layers by converting the CUBE Depth surface and associated Final Uncertainty surface of a PFM grid to a BAG.

This process was done through the use of the Convert PFM to BAG utility in **SABER**. This utility allowed two user-selected surfaces of a PFM (one PFM depth surface and one PFM uncertainty surface) to be converted into one or more BAG layers. 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. All standard deliverable BAG files for this project were exported from the CUBE Depth surface and the Final Uncertainty surface within the CUBE PFM grid, and maintain a one-meter grid resolution.

The Convert PFM to BAG utility is able to 'subdivide' the PFM file during the conversion to BAG, in order to generate multiple smaller BAG files. Based on a request by AHB, SAIC limits the resulting BAG file sizes to 300 megabytes (MB) in size. Therefore, multiple BAGs were produced from a single CUBE PFM grid. To generate multiple BAGs from a single PFM, **SABER** first divides the PFM into an equal number of rows based on the user defined maximum allowed BAG file size. **SABER** then exports each group of rows to the number of BAG files necessary.

Each generated BAG file also has an associated 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 it is associated with, such as the UTM projection, bounding coordinates, horizontal datum, and node spacing. The generated XML metadata files were then opened and edited with a text editor program 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 the depth and uncertainty values of each node within the BAG files, to the depth and uncertainty values of the same node within the PFM layers the BAG was generated from. This was done to ensure that all values are exported and generated correctly in the BAG files, and that no values were dropped during the generation of the BAG files.

Along with the standard deliverable BAG files for this project, separate BAG files were generated for areas throughout the survey with significant features, as required by the April 2010 HSSD. These feature area BAG files were generated from the CUBE Depth surface and the Final Uncertainty surface of the associated feature area CUBE PFM grids. Half-meter grid resolution was used for feature BAG files to comply with the coverage and resolution requirements of the Object Detection Coverage, Section 5.2.2.1, of the April 2010 HSSD.

As requested by NOAA's AHB, and to provide the additional grid node attributes listed in Section 5.2.1.2 of the April 2010 HSSD, six additional non-standard BAG files, corresponding to each of the standard BAG files, were generated. These non-standard BAG files were created with a CUBE Depth layer, populating the Depth layer of the BAG, and each of the following Child layers populating the Uncertainty layer of the BAG:

- CUBE Number of Hypotheses
- CUBE Hypothesis Strength
- CUBE Number of Soundings
- CUBE Standard Deviation
- Standard Deviation
- Average TPU

A detailed description of these layers can be found in Section B.2.4 above, with the exception of the Standard Deviation layer. The Standard Deviation surface contains the standard deviation of the valid soundings within each bin.

Please note that when reviewing these additional, nonstandard, BAGs that the filename designates the layer which populates the Uncertainty layer of the BAG. Please also note that when displayed the two layers of the BAG remain named Depth and Uncertainty. These nonstandard BAGs are provided for review purposes only and are not intended to be used as archival products.

B.2.6 S-57 Feature File

Included with each sheet's delivery is a S-57 feature file made in accordance with the IHO Special Publication No. 57, "*IHO Transfer Standard for Digital Hydrographic Data*", Edition 3.1, (IHO S-57) and Section 8.2 of the April 2010 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. SAIC 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 SAIC maintains the source code which drives the use of the SevenCs ECDIS Kernel so that S-57 feature files can be created through **SABER**.

Any aids to navigation that fell within the bounds of Project OPR-D302-KR-10 are discussed within each sheet's DR. When aids to navigation are privately maintained the resulting feature was included in the respective sheet's final S-57 feature file. However, as stated in the Section 8.2 of the April 2010 HSSD, navigational aids that are maintained by the U.S. Coast Guard are not included with the final S-57 feature file.

Feature depths were attributed within the S-57 feature file (.000) as value of sounding (VALSOU), and were maintained to at least centimeter precision, and when possible based on sonar resolution, 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 April 2010 HSSD. Also, following the IHO S-57 standard and Section 8.2 of the April 2010 HSSD, each sheet's S-57 feature file is delivered in the WGS84 datum and is un-projected with all units in meters.

In addition to the Feature Correlator Sheets delivered in Appendix II of each DR, they were included under the pictorial representation (PICREP) attribute within the S-57 feature file, as requested by AHB. However, the manner in which SAIC generates the S-57 feature file is restricted to maintaining the IHO S-57 standard. At this time, SAIC can only attribute PICREP, when the object class is defined to have the PICREP attribute available. Therefore, for this project only wrecks have the feature correlator, as a .TIF file, listed for PICREP.

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

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. Ping and 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 selected and why it is selected (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 binary codes are converted into hex numbers for display in **ExamMB/ExamGSF**. 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 though 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-codes are converted into hex numbers and two letter code for display in **ExamMB/ExamGSF** and **MVE**. 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.

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

Note that there are deficiencies within the CARIS mapping of multibeam GSF ping and beam flags. These deficiencies are incurred upon the import of multibeam GSF files into CARIS, where flag codes are not yet available to map to the GSF ping and beam flags. These deficiencies are observed in the representation of delayed heave applied, GPSZ applied, the applied tide type in use, and Class1 not being met. 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-3. 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.

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

Table B-4. 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.

GSF Ping Flags		CARIS HIPS Flag	
Bitmask	Comments	Name	Comments
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 SIDESCAN SONAR DATA PROCESSING

During data acquisition, the Klein 3000 digital sidescan data were recorded in 16-bit XTF format (preserved at full resolution) on the hard disk of the Klein 3000 acquisition computer. After the filename change at the end of each line, the sidescan data files were archived to the on-board NAS. On-board sidescan data processing included, at a minimum, generating towfish track plots and initial imagery mosaics for coverage verification and QC. Initial data review and contact generation was also performed on-board the vessel. All original and processed sidescan data files were backed up on digital tapes and external hard drives for transfer to the DPC.

Either on-board the vessel or at the DPC, initial processing also included re-navigating the towfish to apply more accurate towfish positions using the **SABER** Navup routine. This routine was run on all delivered sidescan data, therefore all sidescan data are delivered with completely corrected sidescan sonar positions. This routine replaced the towfish positions (sensor X and sensor Y fields) recorded in the original sidescan 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 position and heading for each ping record (as opposed to the 1 Hz position 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

During examination of sidescan sonar data, a sidescan review log was generated for each sheet, and maintained throughout final data processing. This review log incorporated all of the relevant information about each sidescan data file, including the line begin and line end times, survey line name, corresponding multibeam and sidescan file names, 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 area, 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 sidescan range-scale setting, the watch standers initials, the sidescan model in use and whether or not a depressor was in use on the sidescan, and the weather and sea conditions. These and any other necessary annotations were captured in the review logs prior to the beginning of survey operations in each area, and were continuously updated throughout survey operations as needed in accordance with Section 8.3.3 of the April 2010 HSSD.

During the subsequent sidescan data review stages, the review logs were updated to reflect data quality concerns, highlight data gaps (due to refraction, fish, etc.), identify significant sidescan contacts, and address any other pertinent issues regarding interpretation of the sidescan data. Each sheet's sidescan review log is included in Separates I of the sheet's Descriptive Report.

B.3.1 Sidescan Quality Review

During the sidescan data review, a hydrographer conducted a quality review of each sidescan file using Triton **Isis** to review the data. During this review, the hydrographer assessed the overall quality of the data and defined any holidays in the data where the quality was insufficient to clearly detect seafloor contacts across the full range scale. The times and descriptions for any defined data holidays were entered into the sidescan review log. The times of all noted sidescan data gaps were incorporated into the sidescan data time-window files that were then used to depict the data gap within the applicable sidescan coverage mosaic as discussed in Section A.7. Data holidays were generally characterized by:

- Surface noise (vessel wakes, sea clutter, and/or waves)
- Acoustic noise
- Density layers (refraction)

- Towfish motion (yaw and heave)
- Electrical noise

B.3.2 Sidescan Coverage Analysis

The Project Instructions required 200% sidescan coverage for all depths. The 200% sidescan coverage was verified by generating two separate 100% coverage mosaics. To do this, a time-window file listing the times of all valid online sidescan data was created, along with separate sidescan file lists for the first and second 100% coverage mosaics. Using **SABER**, the time-window file and the sidescan file lists were then used to create one-meter cell size mosaics in accordance with Section 8.3.1 of the April 2010 HSSD. The first and second 100% coverage mosaics were reviewed using tools in **SABER** to verify data quality and swath coverage. 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 200% sidescan sonar coverage, unless otherwise noted in a sheet's Descriptive Report.

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

B.3.3 Sidescan Contact Analysis

During sidescan data review, sonar contacts were selected and measured using the **Isis Target** utility. Significant sidescan 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 selected. Within charted fish havens, contacts were made on objects with a least depth less than the authorized minimum depth, as well as all wrecks, and/or unusually large objects, and on an object to represent general distribution of materials within the fish haven or to represent a large debris field. Contacts with a unique sonar signature (e.g. size, shape, and reflectivity) were typically selected regardless of height. Contacts made within **Isis** were saved as ".CON" files, which included a snapshot of the image and the following contact information:

- Year and JD
- Time
- Position
- Fish altitude
- Slant range to contact (Note: port = negative #, starboard = positive #)
- Contact length, width, and height (based on shadow length, fish altitude, and slant range)

During sidescan data review in **Isis**, the Average Display Down Sample Method was used because it provided the best general-purpose review setting. This setting specifies how the data will be sampled for display in the waterfall display. Down sampling is necessary because the number of pixels displayed is constrained by the width of the display window and the screen resolution. The Triton **Isis Target** utility does not down sample the sidescan data to display the sonar image. If the number of samples contained in the sidescan data record exceeds the number of pixels available on the screen, the software will only show a portion of the record at a single time and provides a scroll bar to be able to view the remaining part of the record. When measuring contacts within Triton **Isis Target**, the length is always the along track dimension and the width is always the across track dimension. Therefore you can have a width measurement that is longer than the length measurement.

Wrecks and large objects were positioned at their highest point based on the observed acoustic shadow. Similarly, contacts for debris fields were positioned at the highest object in the debris field. Additional contacts were made on other man-made objects such as exposed cables, pipelines, and sewer outfalls, if present. In addition to contacts, the sidescan review log also includes entries for many non-significant seafloor objects (e.g., fishing gear, small objects, etc.) that were identified during the sidescan data review. The sidescan review log is included in Separates I of the DR for each sheet.

After a second independent QC review of the sidescan data was complete; all of the sidescan contact files were converted into a single sidescan contact (CTV) file, and separate tiff images of each contact were generated. This was done using the **isis2ctv** program in **SABER**. The CTV file lists all of the contact attributes contained in each of the individual contact files. In **SABER**, the CTV file was viewed as a separate data layer along with a gridded depth layer and multibeam feature file (CNT). By comparing the multibeam bathymetry with the sidescan contact data, both datasets could be evaluated to determine the significance of a contact and the need to create additional sidescan contacts or multibeam features. Positions and depths of features were determined directly from the multibeam data in SAIC's **MVE** swath editor by flagging the least depth on the object. A multibeam 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. The final correlation of the sidescan contacts and multibeam features was done in **SABER** which updated the CNT file with the type of feature (obstruction, wreck, etc.) and the CTV file with the feature number and depth in the related contacts information field.

SAIC exports sidescan contact images, and they are delivered in three different ways. The first is through the Sidescan Sonar Contacts S-57 file utilizing the pictorial representation attribute (PICREP). The second involves only sidescan contacts that have been correlated to a feature, in which case the images are visible in the Feature Correlator Sheets, found in Appendix II of each sheet's DR. Finally, all sidescan contact images (.tif) and **Isis** contact files (_n.CON files) are delivered in Separates V of each sheet's DR. The **Isis** contact files (_n.CON) can be viewed with **Isis Target**. The contact positions stored in these files are the last click positions as chosen by the hydrographer to represent the position with the least depth, not the automatic positioning that is calculated by **Isis**. SAIC's **isis2ctv** program, uses the last click position chosen by the hydrographer as the stored position for the contact. When the **isis2ctv** program is run it overwrites the **Isis** calculated position field in the *n_.CON file with the last click position.

B.3.4 Sidescan Sonar Contact S-57 File

As requested from NOAA AHB, in addition to the required Sidescan Contact List delivered in Appendix II of each sheet's DR, SAIC also generated supplemental S-57 files to display the sidescan sonar contacts for each sheet. The supplemental Sidescan Sonar Contacts S-57 files (.000) were generated through the same process used to build each sheet's final S-57 feature file, described in Section B.2.6, except with sidescan contact information incorporated in the feature file in place of multibeam features.

Please note that for each sheet, the delivered final S-57 feature file (.000) and the delivered Sidescan Sonar Contacts S-57 (.000) file, share the same filename, therefore with each sheet's final delivery the two files are located under different directories.

Within the Sidescan Sonar Contacts S-57 file, sidescan contacts were represented using an object from the Cartographic Object Classes: Cartographic Symbol ($CSYMB). All sidescan contacts for each sheet were delivered in the respective Sidescan Sonar Contacts S-57 file, regardless of the contacts significance. The information field (INFORM) of each cartographic symbol provides specifics regarding the contact it represents, such as; the contact name, sequential id, length, width, height, shadow length, range scale, slant range, altitude, and whether or not the contact was correlated to a multibeam feature. Contacts that were correlated to a multibeam feature include the corresponding multibeam feature number, and the feature's least depth obtained from multibeam. Also, contacts correlated to a multibeam feature have a linked text file (TXTDSC) which corresponds to the INFORM field of the correlated feature as it appears in the sheet's final S-57 feature file. The pictorial representation field (PICREP) of each cartographic symbol details an associated tiff image for the sidescan contact it represents. All sidescan contacts within each sheet's Sidescan Sonar Contacts S-57 file have an associated tiff image file which is delivered with the Sidescan Sonar Contacts S-57 file.

For spatial reference the meta-objects provided in the final S-57 feature file are also in the Sidescan Sonar Contacts S-57 file.

C. CORRECTIONS TO ECHO SOUNDINGS

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

C.1 VESSEL CONFIGURATION PARAMETERS

Figure C-1 depicts the *M/V Atlantic Surveyor* sensor configuration and the vessel offsets for the RESON 8101. The vessel offsets are tabulated in Table C-1. All measurements are in meters. The RESON 8101 ER transducer was hull-mounted approximately amidships, just port of the keel. Offset measurements were made from the POS/MV IMU to the acoustic center of the RESON 8101 ER transducer.

The SAIC **ISS-2000** and the POS/MV utilize a coordinate system where “Z” is considered to be positive down, “X” is considered to be positive forward, and “Y” is considered to be positive to starboard. Sensor offsets were entered into either the POS/MV (offsets referenced to the IMU) or **ISS-2000** (offsets referenced to the sonar acoustic center) (Table C-1). All final data products from any given sensor are in this same coordinate system.

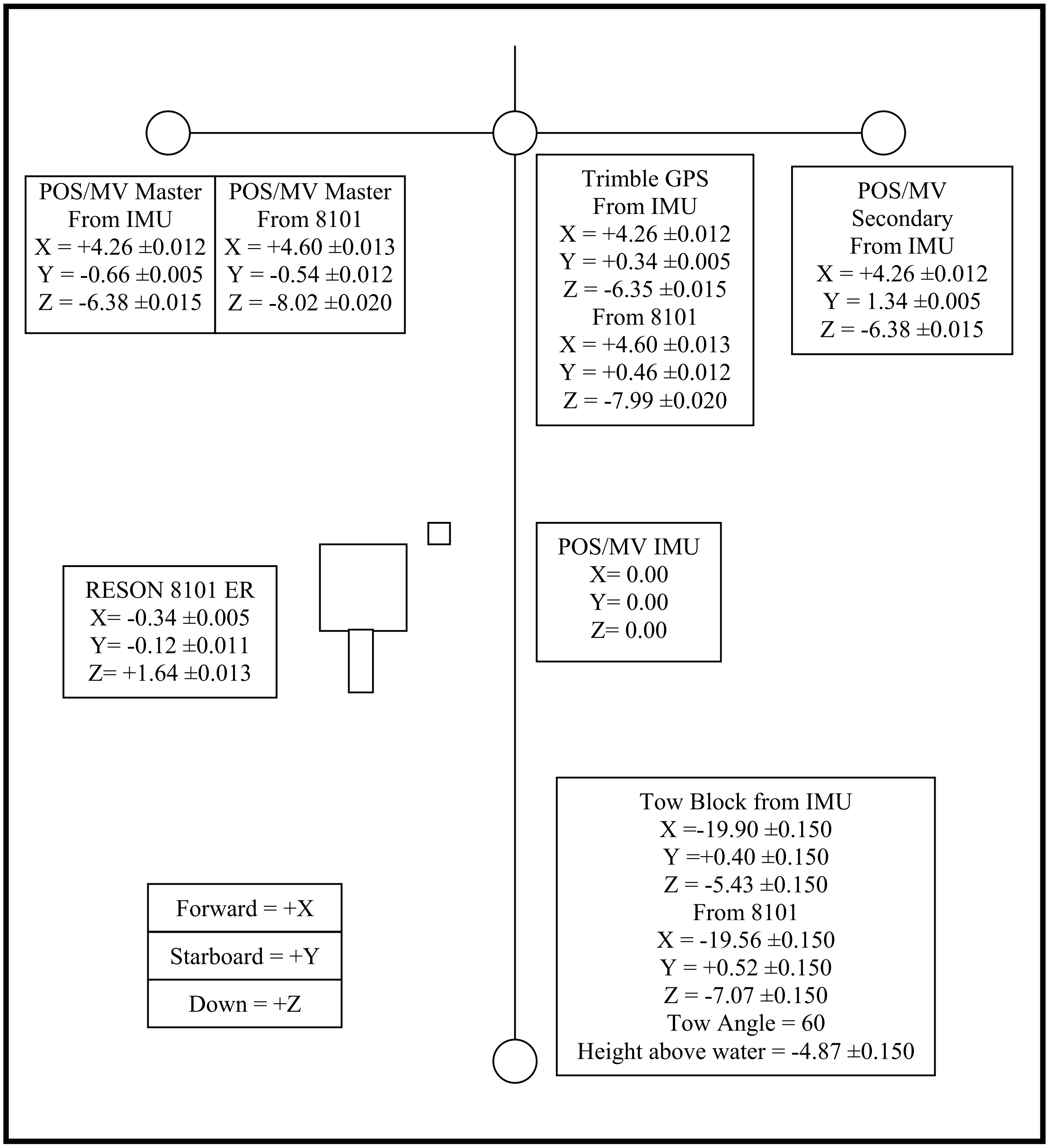

Figure C-1. Configuration and Offsets of *M/V Atlantic Surveyor* Sensors for the RESON 8101 (measurements in meters with 68% CI measurement errors)

Table C-1. *M/V Atlantic Surveyor* Antenna and Transducer Offsets Relative to the POS/MV IMU Vessel Reference Point, measurements in meters

Sensor	Offset in ISS-2000		Offset in POS/MV	
Multibeam RESON 8101 ER Transducer Hull Mount			X	-0.34 ±0.005
			Y	-0.12 ±0.011
			Z	+1.64 ±0.013
Reference to Heave			X	0.00
			Y	0.00

Sensor	Offset in ISS-2000		Offset in POS/MV	
			Z	0.00
Reference to Vessel			X	-0.34 ±0.005
			Y	-0.12 ±0.011
			Z	+1.64 ±0.013
POS/MV GPS Master Antenna			X	4.26 ±0.012
			Y	-0.66 ±0.005
			Z	-6.38 ±0.015
Trimble GPS Antenna From RESON 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 8101 ER Transducer. Z is height above water).	X	-19.56 ±0.150		
	Y	+0.52 ±0.150		
	Z	-4.87 ±0.150		

C.2 STATIC AND DYNAMIC DRAFT MEASUREMENTS

C.2.1 Static Draft

Figure C-2 shows the draft calculations for the *M/V Atlantic Surveyor*. The RESON 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, plus the thickness of the bar 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.2.1.1). The two draft measurements (port and starboard) and the resulting draft value were recorded in the acquisition Navigation Log as well as in a separate vessel Draft Log. If the static draft value changed from the previously noted value, the new value was entered into the **ISS-2000** system. The observed and prorated static draft for each survey is included with the survey data in Section I of the Separates of each sheet's Descriptive Report.

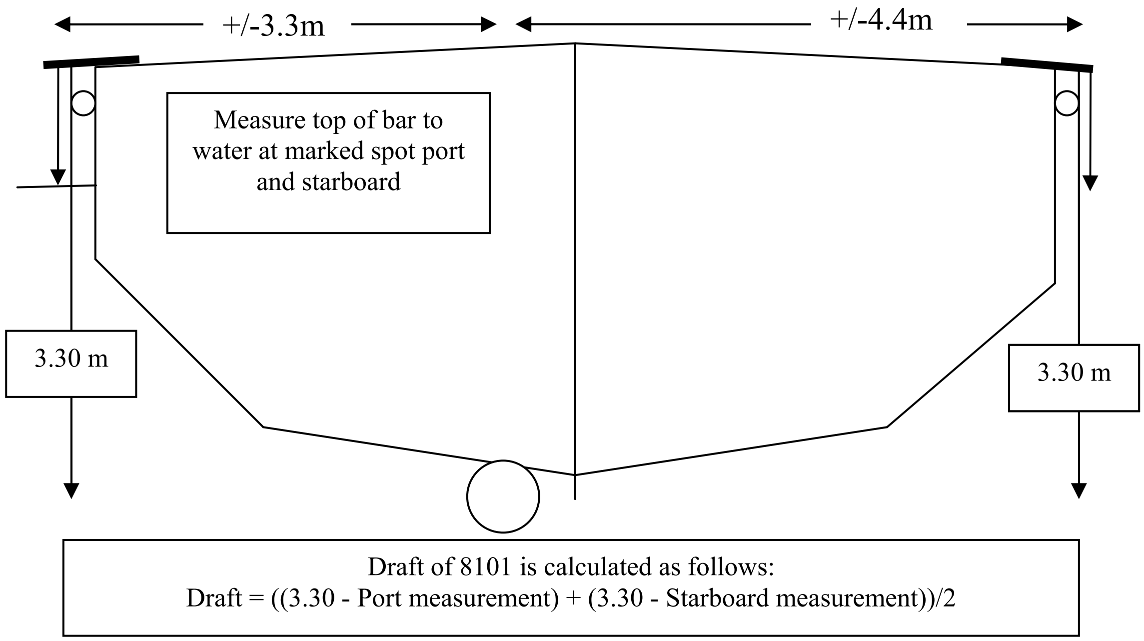

Figure C-2. *M/V Atlantic Surveyor* Draft Determination

C.2.1.1 Prorated Static Draft

An initial processing step of SAIC's data processing pipeline is to apply, if necessary, prorated static draft values to all multibeam data. This is 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.2.1, the static draft was measured and recorded both prior to departure for the survey site, and immediately upon arrival to port after each survey leg. These two observed static draft measurements for each survey leg were then used to calculate the amount of change in the vessel static draft (in meters) observed over that survey leg. For a given period of survey, the change in vessel static draft divided by the number of consecutive days of survey resulted in the amount of change in vessel static draft per day. This daily change in the static draft was then subtracted from the observed static draft value at the beginning of that specific period of survey. This resulted in a unique prorated static draft value for each consecutive survey day that was then applied to the data for that day.

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

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

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

The observed and prorated static draft for each survey is included with the survey data in Section I of the Separates of each sheet's Descriptive Report.

C.2.2 Dynamic Draft

Dynamic draft values were confirmed during the Sea Acceptance Test (SAT) conducted on 07 April 2010. An initial depth reference surface was created by stopping the vessel and acquiring multibeam data as the vessel drifted with the prevailing wind and current. A survey transect was then established perpendicular to the reference surface. This transect was run twice (once in each direction) at each of the six shaft rpm settings. This test was conducted on JD 096 (2010) to determine the settlement and squat correctors and then re-run on JD 097 (2010) to verify the settlement and squat values entered into the vessel configuration file. Separate 0.5-meter PFM and minimum grids were created using the near-nadir (5 degree) beams for the drift reference line and each of the RPM pairs. Difference grids were then created between the CUBE depth in the PFM grid as well as from the minimum grids from the drift reference line and each of the RPM pairs. The resulting difference grids were then analyzed using **SABER's** Frequency Distribution tool. This tool allowed the hydrographer to visually and numerically view the distribution of depth differences between each RPM pair and the reference drift line. Settlement and Squat values were determined to the nearest centimeter to satisfy the 0.05-meter precision requirement stated in Section 5.2.3.2 of the April 2010 HSSD. Table C-2 summarizes the shaft RPM, depth corrector, approximate speed, and 2010 SAT multibeam files used. The values determined from the analysis were entered into a look up table within the **ISS-2000** system. A shaft RPM counter provided automatic input to the **ISS-2000** system which in conjunction with the look up table applied a dynamic settlement and squat value as data were collected.

Table C-2. *M/V Atlantic Surveyor* Settlement and Squat Determination 2010

Shaft RPM	Depth Corrector	Approximate Speed (Kts)	1-Sigma	Files	
				JD 096	JD 097
0	0.00	0	0.00	asmba10096.d49	asmba10097.d98
140	-0.02	4	0.018567	asmba10096.d50	asmba10097.d97 asmba10097.d47
180	-0.01	5	0.017429	asmba10096.d51	asmba10097.d48
250	0.01	6	0.018893	asmba10096.d52	asmba10097.d49

Shaft RPM	Depth Corrector	Approximate Speed (Kts)	1-Sigma	Files	
				JD 096	JD 097
300	0.06	8	0.003952	asmba10096.d53 asmba10096.d54	asmba10097.d50
340	0.010	9	0.008186	asmba10096.d55	asmba10097.d51
380	0.12	10	0.009858	asmba10096.d56 asmba10096.d57	asmba10097.d52

C.2.3 Speed of Sound

A Moving Vessel Profiler (MVP), manufactured by Brooke Ocean Technology Ltd., with an Applied Microsystems Ltd. SV&P Smart Sensor, was used to determine sound speed profiles for corrections to multibeam sonar soundings.

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

During multibeam acquisition, SSP casts were uploaded to **ISS-2000** immediately after they were taken. In **ISS-2000**, the profiles were reviewed for quality and 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 cast 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 cast 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, and observed changes from the previous profiles. At a minimum, casts were taken at the beginning and end of each survey leg, at approximately one-hour intervals thereafter, and upon moving to a different survey area.

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

A Sound Speed Profile Log including details of all SSP casts, (such as date, location, application times, and maximum depth) is located in Section II of the Separates of each sheet’s DR. These Logs are provided as an Excel spreadsheet and associated PDF. These Logs are separated by the purpose of the applied cast, and thereby categorized by SSP files which were: “Used_for_MB” (applied to online bathymetry data), “Used_for_Closing_Casts”, “Used_for_Comparison_Cast”, and “Used_for_Lead_Line”.

Additionally, in a separate folder within Separates II, CARIS_SSP, there are four .svp files. These four files contain concatenated SSP data that has been formatted for use in CARIS. The CARIS SSP files are designated based on the purpose of the cast and their filenames match the tabs within the sound speed profile log.

C.3 MULTIBEAM CALIBRATIONS

Initial Sea Acceptance Tests (SAT), with a Reson 7125 multibeam system, were conducted on 07 April 2010 prior to the start of data acquisition for the 2010 survey season. The RESON 7125 was struck by an unknown submerged object during transit to port on 04 November 2010 (JD 308). The *M/V Atlantic Surveyor* was then dry docked on 11 November 2010 to asses and repair damages to the multibeam system and hull mount. Operations included the removal of the damaged RESON 7125 sonar equipment, inspection of the vessel and sonar hull mount, installation of new equipment, and measurement of offsets for the RESON 8101 sonar system. All dry dock operations were conducted between 11 November 2010 and 13 November 2010.

The RESON 8101 ER transducer was then installed by diver on the *M/V Atlantic Surveyor* on 14 November 2010, after the vessel had left dry dock. Complete SAT operations with the exception of settlement and squat followed the installation of the RESON 8101 on 15 November 2010. This SAT included; a ping timing test completed to verify that no timing errors existed within the survey system; a multibeam patch test was conducted to determine bias values for roll, pitch, and heading; and a survey was run to analyze multibeam accuracies after the installation of the RESON 8101. During the original SAT conducted on 07 April 2010 SAT, settlement and squat values for the dynamic draft of the vessel were determined. The settlement and squat values determined from that test (referenced in Table C-2) remained the same throughout the completion of data acquisition on H12161 in 2010. All other SAT results which pertain to data collected on sheet H12161 (conducted on 15 November 2010) are described in detail below.

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.4 for details of delayed heave and the application process).

C.3.1 Timing Test

A ping timing test was completed on 05 November 2010 for the RESON SeaBat 8101 ER to verify that no timing errors existed within the survey system. The fundamental tool is the event marking capability of the Symmetricom BC635PCI IRIG-B card. An event is characterized by a positive-going TTL pulse occurring on the event line of the IRIG-B connector on the back of the ISSC. The pulses of interest are the transmit trigger of the RESON 81-P and the 1PPS timing pulses from the POS/MV. These tests demonstrated that all GSF ping times matched the corresponding IRIG-B event times to within 2.5 milliseconds or less (Figure C-3).

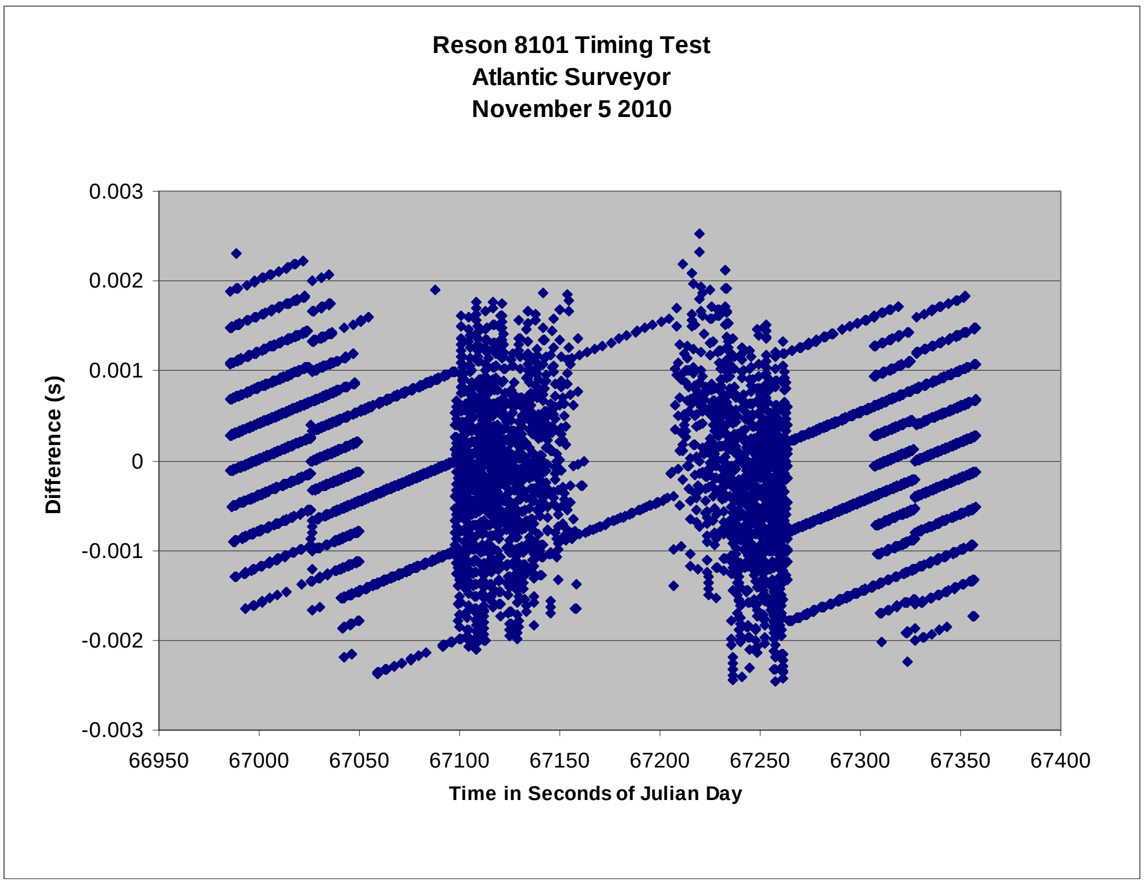

Figure C-3. 05 November 2010 RESON 8101 Timing Test Results (time differences of ping trigger event vs. ping time tag from GSF)

C.3.2 Multibeam Bias Calibration

Roll, pitch, and heading biases were determined on 15 November 2010 over a 47 foot wreck in the fish haven approximately six kilometers southeast of Manasquan Inlet. The wreck is charted in 40° 03.3925'N 073° 59.5541'W. Final biases are presented in Table C-3.

Table C-3. Multibeam Files Verifying Alignment Bias Calculated using the Swath Alignment Tool (SAT) - 15 November 2010 RESON 8101

Component	Multibeam Files		Result
Pitch	81mba10319.d24	81mba10319.d25	+0.690°
Roll	81mba10319.d24	81mba10319.d25	+0.661°
Heading	81mba10319.d22	81mba10319.d23	+1.40°

Two sets of lines were collected for pitch bias calculation. All lines were run along the same survey transect in order for separate comparisons to be made between lines run in opposite directions. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the pitch bias. Figure C-4 and Figure C-5 are images of the **SAT** tool depicting data collected with the +0.690° pitch bias entered in the **ISS-2000** system; therefore the indicated bias is zero.

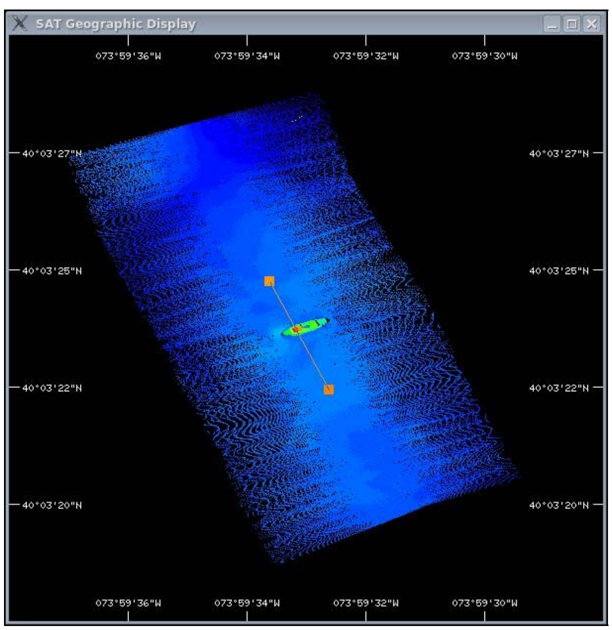

Figure C-4. SAT Tool, Plan View Depicting +0.690° Pitch Bias

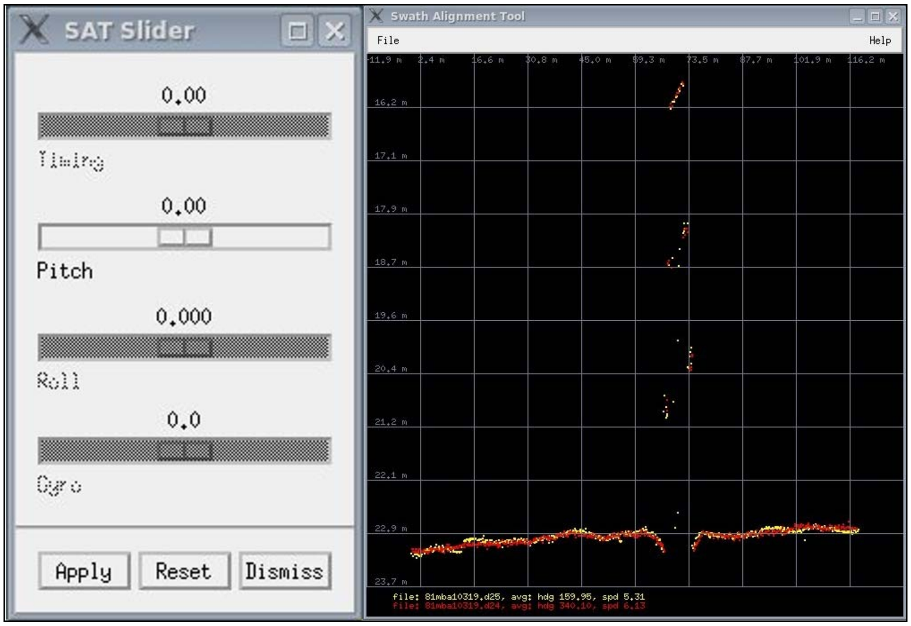

Figure C-5. SAT Tool, Depth vs. Distance Plot Depicting +0.690° Pitch Bias

Two sets of lines were collected for roll bias calculation. All lines were run along the same survey transect in order for separate comparisons to be made between lines run in opposite directions. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the roll bias. Figure C-6 and Figure C-7 are images of the **SAT** tool depicting data collected with the +0.661° roll bias entered in the **ISS-2000** system; therefore the indicated bias is zero.

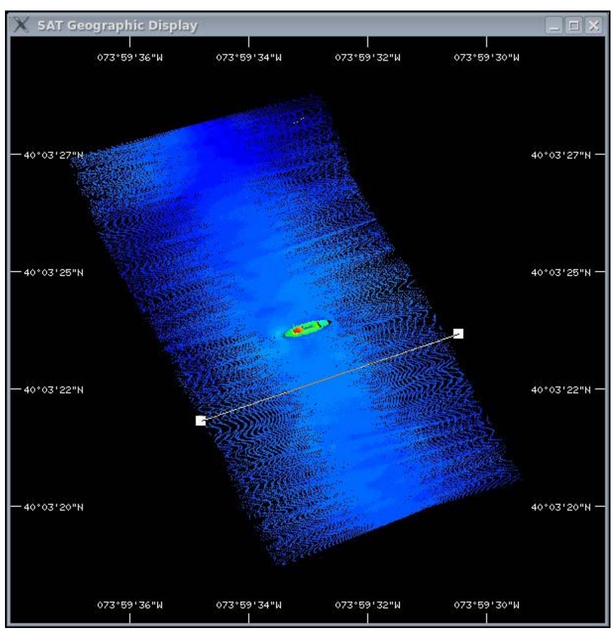

Figure C-6. SAT Tool, Plan View Depicting +0.661° Roll Bias

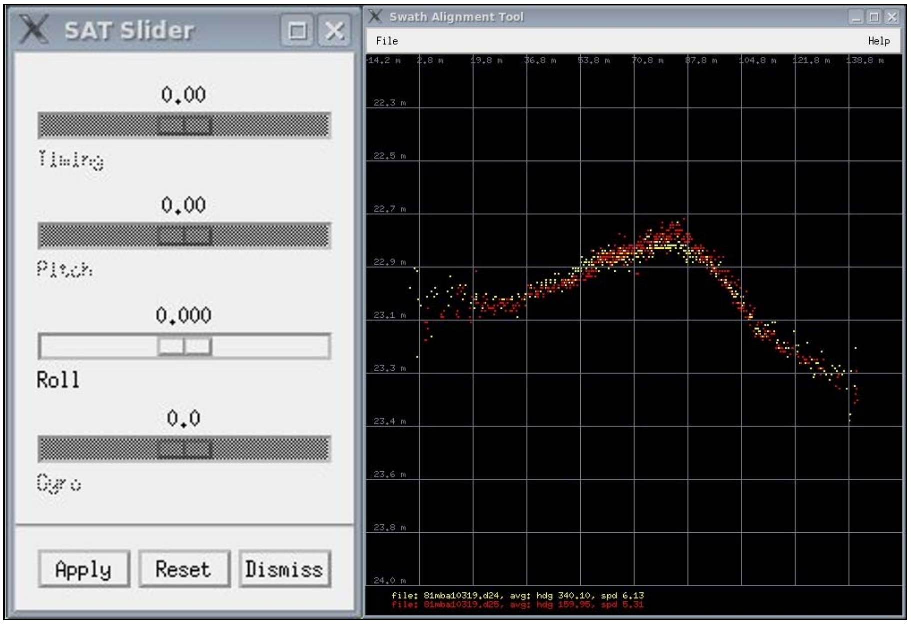

Figure C-7. SAT Tool, Depth vs. Distance Depicting +0.661° Roll Bias

Two sets of lines were collected for heading bias calculation. Lines were run on either side of the charted wreck in opposite directions in order for separate comparisons to be made. Several samples were viewed for each set of comparison lines in order to determine an accurate measurement of the heading bias. Figure C-8 and Figure C-9 are images of the **SAT** tool depicting data collected with the +1.40° heading bias entered in the **ISS-2000** system; therefore the indicated bias is zero.

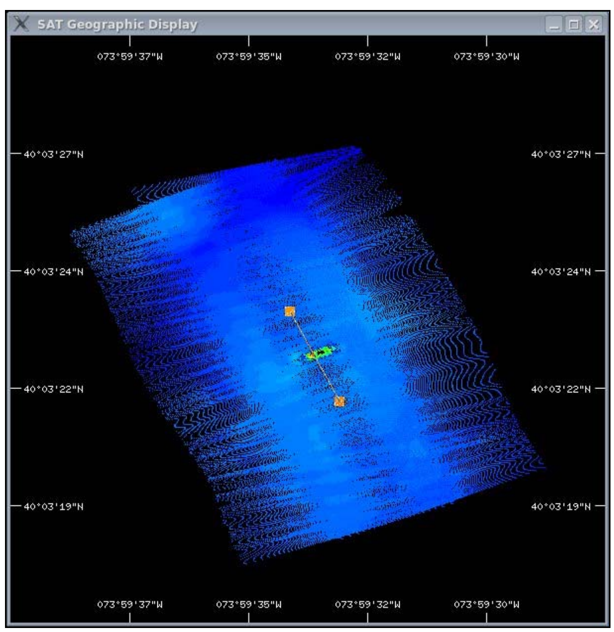

Figure C-8. SAT Tool, Plan View Depicting +1.40° Heading Bias

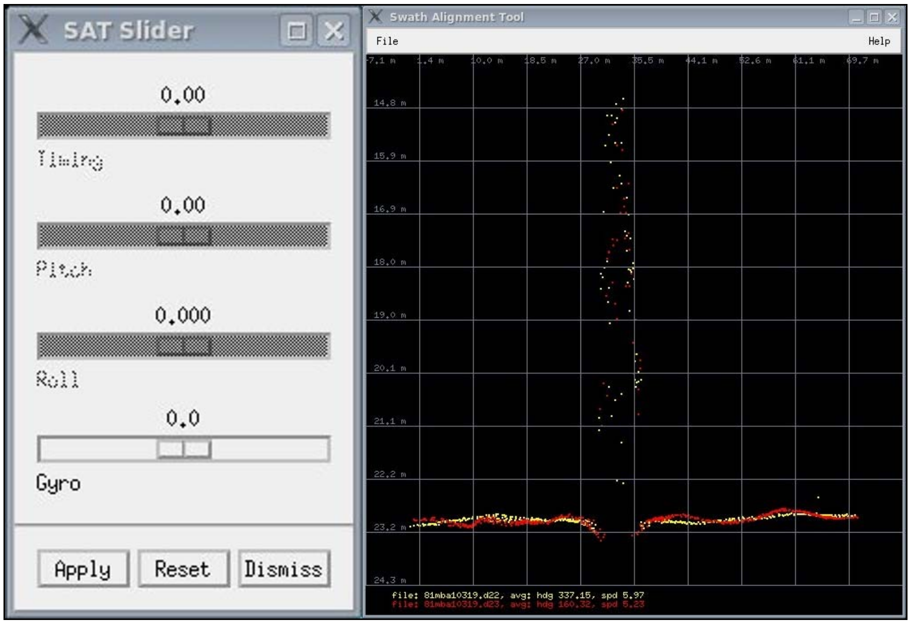

Figure C-9. SAT Tool, Depth vs. Distance Depicting +1.40° Heading Bias

C.3.3 Multibeam Accuracy

During the 15 November 2010 SAT, a survey was run in the vicinity of the wreck alignment site to analyze multibeam accuracies after the installation of the RESON 8101. This survey consisted of nine main scheme lines and three crosslines centered on the wreck. All depths were corrected for observed tides and zoning using the Atlantic City tide gage, 8534720. The class1 cutoff angle was set to 5° and the class2 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, class1 crosslines, and all lines were created. A one-meter PFM of all the data was also generated and the Gap Checker and Check Uncertainty routines were run on the PFM CUBE depth layer. Multibeam features, sidescan contacts, and selected soundings in feet were generated. The resulting minimum grid with selected soundings (in feet) is shown in Figure C-10. The PFM with CUBE depths and uncertainties are shown in Figure C-11 and Figure C-12, respectively.

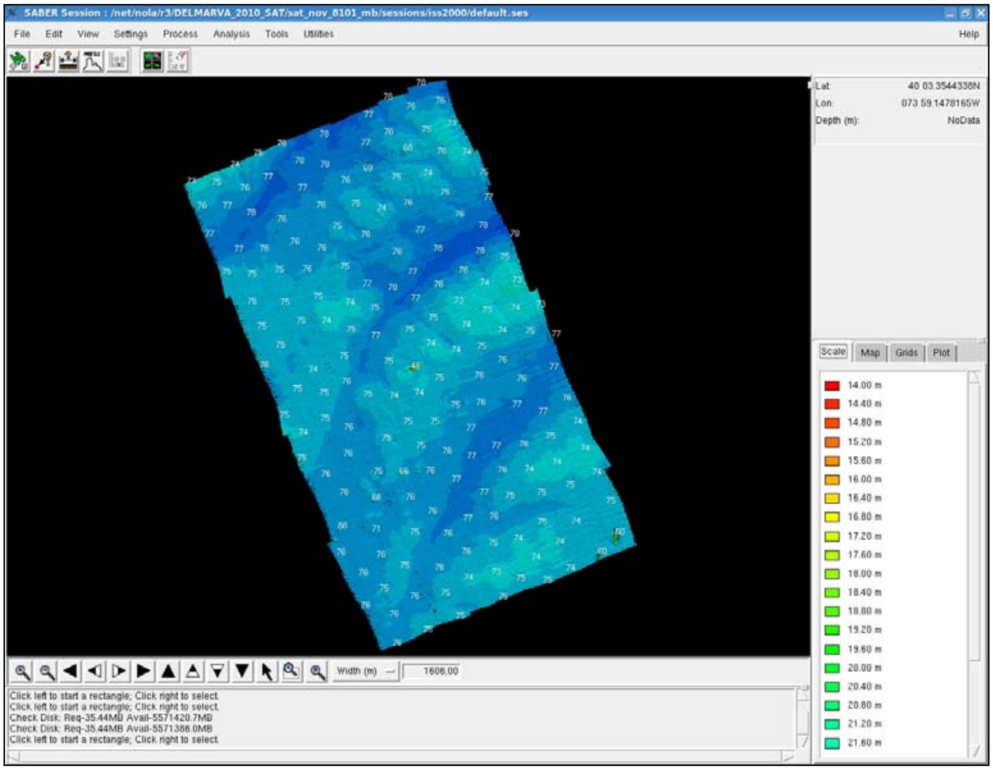

Figure C-10. 15 November 2010 SAT - RESON 8101 Verification Survey Minimum Depth Grid and Selected Soundings

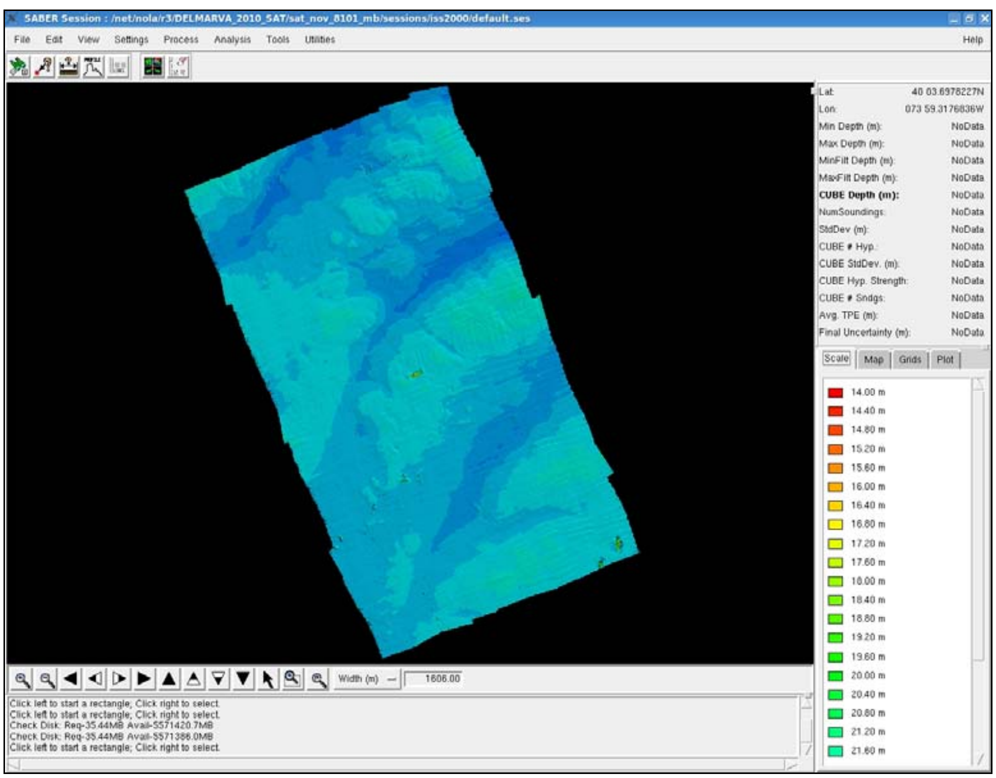

Figure C-11. 15 November 2010 SAT - RESON 8101 PFM CUBE Depth Layer

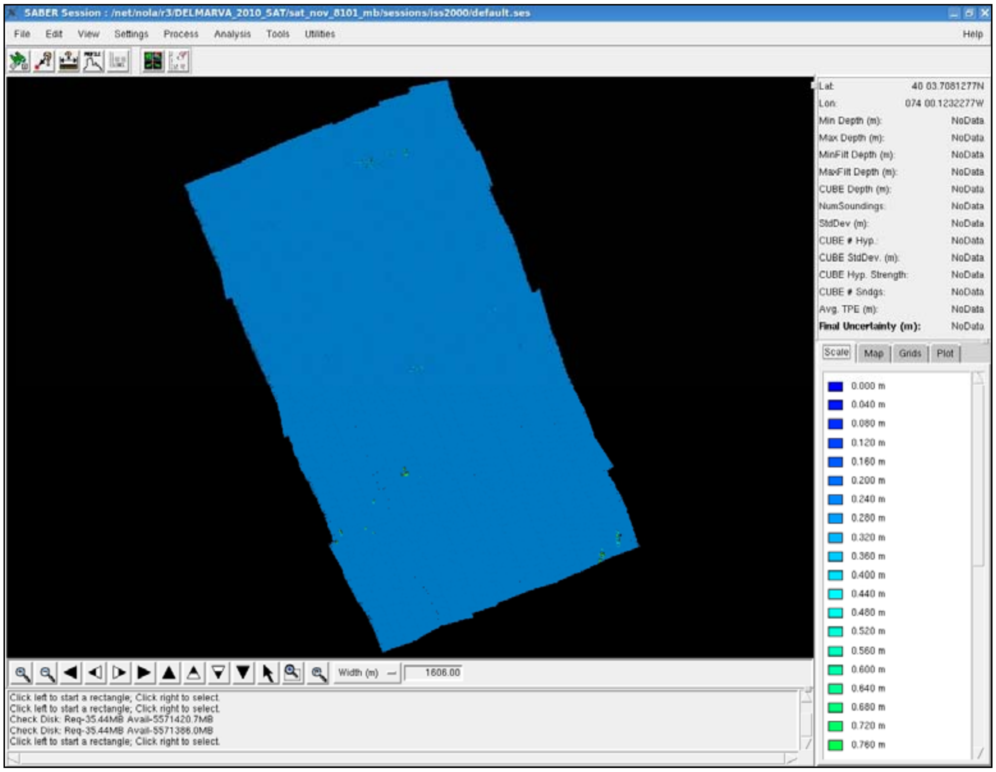

Figure C-12. 15 November 2010 SAT - RESON 8101 PFM Uncertainties Layer

A depth difference grid between the one-meter main scheme and the class1 crossline grids was created. A statistical analysis of the depth differences using the Frequency Distribution tool in **SABER** was performed. The results of the statistical analysis showed that 99% of the depths agree to less than 0.20 meters, and 100% of the depths agree to less than 0.25 meters (Table C-4). The junction analysis results for the depth differences between the main scheme and crosslines are reported in Table C-4 showing agreement between values.

Junction analysis was performed by subtracting the 15 November 2010 class1 crossline grid from the 15 November 2010 main scheme grid. Therefore, negative values indicate that 15 November 2010 main scheme data are shoaler than 15 November 2010 crossline data. The main scheme data were shoaler than the crossline data in 27.16% of junctions and the main scheme data were deeper than crossline data in 66.46% of the junctions across the entire survey area.

Table C-4. 15 November 2010 SAT - RESON 8101 Frequency Distribution of Depth Differences Between the Class One Crossline Minimum Grid and the Main Scheme Minimum Grid

Depth Difference (Meters)	Bins	Cumulative Percent	Positive Bins	Positive Cumulative Percent	Negative Bins	Negative Cumulative Percent	Zero Bins	Zero Cumulative Percent
0.00-0.05	4738	62.32	2602	34.22	1651	21.72	485	6.38
>0.05-0.1	2166	90.81	1795	57.83	371	26.59	-	-
>0.1-0.15	544	97.96	506	64.49	38	27.09	-	-

Depth Difference (Meters)	Bins	Cumulative Percent	Positive Bins	Positive Cumulative Percent	Negative Bins	Negative Cumulative Percent	Zero Bins	Zero Cumulative Percent
>0.15-0.2	149	99.92	145	66.39	4	27.15	-	-
>0.2-0.25	6	99.99	5	66.46	1	27.16	-	-
Total	7603	100.00%	5053	66.46%	2065	27.16%	485	6.38%
Reference Grid: tug_main_1m_pfm_tug_survey_cross_cl1_1m_pfm.dif								

A depth difference grid between the PFM CUBE Depth layers from the 15 November 2010 SAT survey (RESON 8101) and the 20 July 2010 SAT survey (RESON 8101) were also created. A statistical analysis of the depth differences using the Frequency Distribution tool in **SABER** was also performed on this depth difference grid. The results of the statistical analysis showed that 98% of the depths agree to less than 0.25 meters, and 99% of the depths agree to less than 0.30 meters (Table C-5). The junction analysis results for the depth differences between the PFM CUBE depth layers are reported in Table C-5 showing agreement between values.

Junction analysis was performed by subtracting the 20 July 2010 PFM CUBE Depth layer from the 15 November 2010 PFM CUBE Depth layer. Therefore, negative values indicate that 15 November 2010 data are shoaler than 20 July 2010 data. The 15 November 2010 data were shoaler than the 20 July 2010 data in 1.12% of junctions and the 15 November 2010 data were deeper than 20 July 2010 data in 98.37% of the junctions across the entire survey area. This bias towards deeper depths in the 15 November 2010 data can be attributed to the use of predicted tides in the 20 July data and observed tides in the November data.

Table C-5. 15 November 2010 SAT - RESON 8101 Frequency Distribution of Depth Differences Between the 15 November 2010 All PFM CUBE Layer and the 20 July 2010 All PFM CUBE Layer

Depth Difference (Meters)	Bins	Cumulative Percent	Positive Bins	Positive Cumulative Percent	Negative Bins	Negative Cumulative Percent	Zero Bins	Zero Cumulative Percent
0.00-0.05	48936	8.74	40809	7.29	5270	0.94	2857	0.51
>0.05-0.10	129301	31.83	128608	30.26	693	1.06	-	-
>0.10-0.15	200393	67.62	200295	66.03	98	1.08	-	-
>0.15-0.20	138641	92.38	138606	90.78	35	1.09	-	-
>0.20-0.25	36927	98.97	36903	97.37	24	1.09	-	-
>0.25-0.30	4788	99.83	4775	98.22	13	1.10	-	-
>0.30-0.60	758	99.96	713	98.35	45	1.10	-	-
>0.60-1.00	67	99.97	50	98.36	17	1.11	-	-
>1.00-3.00	107	99.99	63	98.37	44	1.11	-	-
>3.00-6.50	39	100.00	23	98.37	16	1.12	-	-
Total	559957	100%	550845	98.37%	6255	1.12%	2857	0.51%
Reference Grid: tug_all_1m_8101_nov_pfm_tug_survey_all_8101_july_pfm.dif								

C.4 DELAYED HEAVE

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

At the start of 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 multibeam GSF files. The delayed heave files 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 helped to reduce 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 multibeam 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 multibeam GSF file. The raw beam angle and travel time values were used along with the vessel attitude (including heave) and re-ray traced. As delayed heave was applied, a history record was written to each GSF file, and the ping flag of each modified ping was updated.

After the application of delayed heave was complete, all multibeam data were reviewed to verify that the delayed heave values were correctly 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 multibeam GSF filename, as well as the time range for the gap in delayed heave application. The data from the **check_heave** reports was then used to further investigate all instances of gaps in delayed heave application.

SAIC strived to have delayed heave applied to all soundings of multibeam data, however there were times when this was not possible. For example, delayed heave is not applied if data logging is stopped without allowing at least three minutes of continuous data logging after the end of a survey line, due to a three minute delay of logging *TrueHeave*™ data from real-time heave data out of the POSMV.

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.

C.5 TIDES AND WATER LEVELS

NOAA tide station 8651370 Duck, NC was the source of final verified water level heights for the Mid-Atlantic Corridor, Coast of Virginia surveys (see supplemental correspondence email string with final date of 03 May 2010, located in Appendix V, and revised tide section for Project Instructions). Preliminary and verified water level data for this station were downloaded from the NOAA Center for Operational Oceanographic Products and Services Tides & Currents web site (http://www.tidesandcurrents.noaa.gov/). All water level data in meters were annotated with Coordinated Universal Time (UTC).

Final water level files for each tide zone were created from downloaded verified tide data using the **SABER** Create Water Level Files tool. Water level files contained water level heights that were algebraically subtracted from depths to correct the sounding for tides and water levels. These water level files were applied to the multibeam data using the **SABER** Apply Offsets Tides program.

When it was necessary to apply updated water level correctors such as verified tides to the GSF files, the program removed the previous water level corrector and applied the new corrector. Each time the program was run on the GSF multibeam data file, 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 Tides Corrections in GSF program was run on all GSF files to confirm that the appropriate water level corrector had been applied to the GSF file.

After confirmation that verified water levels were applied to all multibeam 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.

The primary means for analyzing the adequacy of correctors was observing zone boundary crossings in SAIC's **Multi View Editor**. In addition, cross line analysis using the **SABER Analyze Crossings** software was used to identify possible depth discrepancies resulting from the applied water level corrector. 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. The NOAA provided preliminary zoning parameters are presented in Table C-6.

Table C-6. Preliminary Tide Zone Parameters

Zone	Time Corrector (minutes)	Range Ratio	Reference Station
SA46	0	1.08	8651370
SA46A	0	1.08	8651370
SA55	+6	1.11	8651370
SA55A	0	1.11	8651370

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

C.5.1 Final Tide Note

H12160 and H12161 surveys were entirely within preliminary water level zones SA46, SA46A, SA55, SA55A referenced to NOAA tide station 8651370 Duck, NC. 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.

All data for H12161 were contained within tide zones SA46 and SA46A. The zone correctors were the same for both of these zones and analysis of the multibeam data in **MVE** and in depth grids revealed no depth jumps across the junction of zones SA46 and SA46A.

As a result, the NOAA preliminary zone boundaries and zoning parameters for Duck, NC (8651370) were accepted as final and applied to all multibeam data for H12161. The final analysis of the zone to zone comparisons for sheet H12160, which is yet to be delivered, will be submitted within the Descriptive Report for that sheet.

D. APPROVAL SHEET

25 March 2011

LETTER OF APPROVAL

REGISTRY NUMBER: H12161, H12160

This Data Acquisition and Processing Report for project OPR-D302-KR-10, Mid-Atlantic Corridor, Coast of Virginia Project is respectfully submitted.

Field operations and data processing contributing to the accomplishment of these surveys, H12160 and H12161 were conducted under supervision of myself and lead hydrographers Paul Donaldson, Jason Infantino, Evan Robertson, Chuck Holloway, and Gary R. Davis with frequent personal checks of progress and adequacy. This report has been closely reviewed and is considered complete and adequate as per the Statement of Work.

Reports concurrently submitted to NOAA for this project include:

Report	Submission Date
H12161 Descriptive Report 11-TR-003	25 March 2011

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION

Deborah M. Smith

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Deborah M. Smith
Lead Hydrographer
Science Applications International Corporation
25 March 2011