U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

# Data Acquisition & Processing Report

| | |
|---|---|
| Type of Survey: | Basic Hydrographic Survey |
| Project Number: | OPR-K371-KR-19 |
| Time Frame: | April - September 2019 |

## LOCALITY

| | |
|---|---|
| State(s): | Texas |
| General Locality: | Port Arthur, TX |

## 2019

CHIEF OF PARTY
Paul L. Donaldson

LIBRARY & ARCHIVES

Date:

# Table of Contents

## List of Figures

# Data Acquisition and Processing Report

**Leidos**
Chief of Party: Paul L. Donaldson
Year: 2019
Version: 1
Publish Date: 2019-12-06

# A. System Equipment and Software

## A.1 Survey Vessels

### A.1.1 M/V Atlantic Surveyor

| | |
|---|---|
| *Vessel Name* | M/V Atlantic Surveyor |
| *Hull Number* | M/V Atlantic Surveyor |
| *Description* | For this project Leidos employed one survey vessel, the M/V Atlantic Surveyor which is a 110-foot steel hulled vessel, which was outfitted with the following major data acquisition systems for the survey effort:<br>1. POS/MV 320 version V5 and IMU type 36<br>2. Teledyne RESON SeaBat T50 multibeam echo sounder (MBES) (hull-mounted approximately amidships, just port of the keel)<br>3. Klein 3000 dual frequency SSS (towed)<br>4. AML Oceanographic Moving Vessel Profiler 30 (MVP30) sound speed profile (SSP) acquisition system<br><br>The M/V Atlantic Surveyor (Figure 1) was equipped with shipboard systems including an autopilot, non-survey echo sounder, Differential Global Positioning System (DGPS), radars, Automatic Identification System (AIS), and two 40 kilowatt (kW) diesel generators. Accommodations for up to twelve surveyors were available within three cabins. For survey operations, the SSS winch and four International Organization for Standardization (ISO) containers were secured on the aft deck. The first 20-foot container was used as the real-time survey data acquisition office, the second 20-foot container was used for the onboard data processing office, and the third 20-foot container was used for spares storage, maintenance, and repairs. The fourth 10-foot ISO container mounted on the aft deck housed a 110kW generator that provided dedicated power to the SSS winch, ISO containers, and all survey equipment. The POS/MV IMU was mounted approximately amidships, below the main deck, port of the keel. The RESON SeaBat T50 transducer and collocated AML MicroX surface sound speed sensor were hull-mounted approximately amidships, port of the vessel's keel. The MVP30 was mounted on the starboard stern quarter. Configuration parameters, offsets, and installation diagrams for all equipment are included in the following sections of this Report and Appendices. |
| *Dimensions* | *LOA*: 110 ft<br>*Beam*: 26 ft<br>*Max Draft*: 9 ft |
| *Most Recent Full Static Survey* | *Date*: 2019-01-31<br>*Performed By*: Leidos |

*Figure 1: M/V Atlantic Surveyor*

## A.2 Echo Sounding Equipment

### A.2.1 Multibeam Echosounders

### A.2.1.1 RESON SeaBat T50

A RESON SeaBat T50, hull-mounted approximately amidships, just port of the keel, with an AML MicroX surface sound speed sensor was used for all MBES data collection onboard the M/V Atlantic Surveyor. The RESON SeaBat T50 can be operated in Equi-Angle, Equi-Distant, or Intermediate Modes with a sliding scale of 10 to 512 beams. In all configurations the beams were dynamically focused resulting in a 0.5 degree across-track receive beam width and a 1.0 degree along- track transmit beam width with up to a 150 degree coverage angle in Equi-Distant and Intermediate Modes and up to a 165 degree coverage angle in Equi-Angle Mode.

The RESON SeaBat T50 was primarily set to the 256 beams Intermediate Mode during survey operations, with a 120 degree swath set by the coverage angle in the controller; and was in use as single frequency system operating at 400 kilohertz (kHz). The maximum ping rate was manually set to 30 hertz (Hz). The achievable maximum ping rate was controlled by the range scale, which was typically chosen automatically with the use of tracker mode in the RESON Sonar User Interface (UI). The tracker mode was configured to automatically select the range, power, gain, absorption, spreading, and pulse length. The resulting settings and real-time data quality were continuously monitored by the watchstanders. If ever deemed necessary, the watchstanders based on real-time quality monitoring would disable the automatic tracker mode and manually adjust the system settings. During item investigations, the RESON SeaBat T50 was set to either 256 beams Intermediate or 512 beams Intermediate mode, with occasional adjustments to focus the coverage angle.

During the survey season, the RESON SeaBat T50 receiver began to exhibit a warning message indicating a low PSU voltage output; while there was no loss in data integrity or quality, the system suddenly became unresponsive on 2019-08-06 (Julian Day [JD] 218). The RESON SeaBat T50 receiver and transducer were exchanged in kind with a replacement system which was installed on the ship's hull 2019-08-09 (JD 221).

After the replacement RESON SeaBat T50 projector and receiver arrays were reinstalled, alignments were confirmed via a Patch Test on 2019-08-10. Details of the arrays in use are captured in the Table below; refer to the DAPR Appendices for further information on the Patch Tests performed.

<table>
<tr><td><i>Manufacturer</i></td><td>RESON</td></tr>
<tr><td><i>Model</i></td><td>SeaBat T50</td></tr>
<tr><td><i>Inventory</i></td><td><table><tr><td></td><td><table>
<tr><td><i>Component</i></td><td>Sonar Processor</td><td>Projector</td><td>Projector</td><td>Receiver</td><td>Receiver</td></tr>
<tr><td><i>Model Number</i></td><td>T50-R</td><td>TC2181</td><td>TC2181</td><td>EM7218</td><td>EM7218</td></tr>
<tr><td><i>Serial Number</i></td><td>3716025</td><td>2117070</td><td>1618066</td><td>3216025</td><td>2318045</td></tr>
<tr><td><i>Frequency</i></td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td><i>Calibration</i></td><td>2019-04-10</td><td>2019-04-10</td><td>2019-08-10</td><td>2019-04-10</td><td>2019-08-10</td></tr>
<tr><td><i>Accuracy Check</i></td><td>2019-04-10</td><td>2019-04-10</td><td>2019-08-10</td><td>2019-04-10</td><td>2019-08-10</td></tr>
</table></td></tr></table></td></tr>
</table>

### A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

### A.2.3 Side Scan Sonars

#### A.2.3.1 Klein Marine Systems Inc. 3000

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

The SSS ping rate is automatically set by the TPU based on the range scale setting selected by the user. During OPR-K371-KR-19 based on the planned survey areas, the observed water depths and the observed environmental conditions, the SSS range scale was set by the watchstanders at either 25 meters, 50 meters, or 75 meters. At a range scale of 75 meters, the ping rate is 10 Hz; at a range scale of 50 meters, the ping rate is 15 Hz; and at a range scale of 25 meters, the ping rate is 30 Hz. Based on these ping rates, maximum survey speeds were established for each range scale setting to ensure coverage requirements were met in accordance with Section 6.1.2.2 of the HSSD. During survey operations, the Klein 3000 was towed from the ship's A-Frame while the altitude was controlled by watchstanders via a Sea Mac winch with remote controller. The cable payout was continuously monitored from the MacArtney sheave sensor and logged by ISS-2000.

<table>
<tr><td>*Manufacturer*</td><td>Klein Marine Systems Inc.</td></tr>
<tr><td>*Model*</td><td>3000</td></tr>
<tr><td>*Inventory*</td><td>
<table>
<tr><td></td><td>
<table>
<tr><td>*Component*</td><td>Klein Transceiver Processing Unit (TPU)</td><td>Klein Transceiver Processing Unit (TPU)</td><td>Towfish</td><td>Towfish</td></tr>
<tr><td>*Model Number*</td><td>N/A</td><td>N/A</td><td>3000</td><td>3000</td></tr>
<tr><td>*Serial Number*</td><td>418</td><td>420</td><td>534</td><td>535</td></tr>
<tr><td>*Frequency*</td><td>N/A</td><td>N/A</td><td>100 kHz and 500 kHz concurrently</td><td>100 kHz and 500 kHz concurrently</td></tr>
<tr><td>*Calibration*</td><td>2019-04-10</td><td>2019-04-10</td><td>2019-04-10</td><td>2019-04-10</td></tr>
<tr><td>*Accuracy Check*</td><td>2019-04-10</td><td>2019-04-10</td><td>2019-04-10</td><td>2019-04-10</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

### A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

### A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

## A.3 Manual Sounding Equipment

### A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

### A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

### A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

### A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

## A.4 Horizontal and Vertical Control Equipment

### A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

### A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

### A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

### A.4.4 Levels

No levels were utilized for data acquisition.

## A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

## A.5 Positioning and Attitude Equipment

### A.5.1 Positioning and Attitude Systems

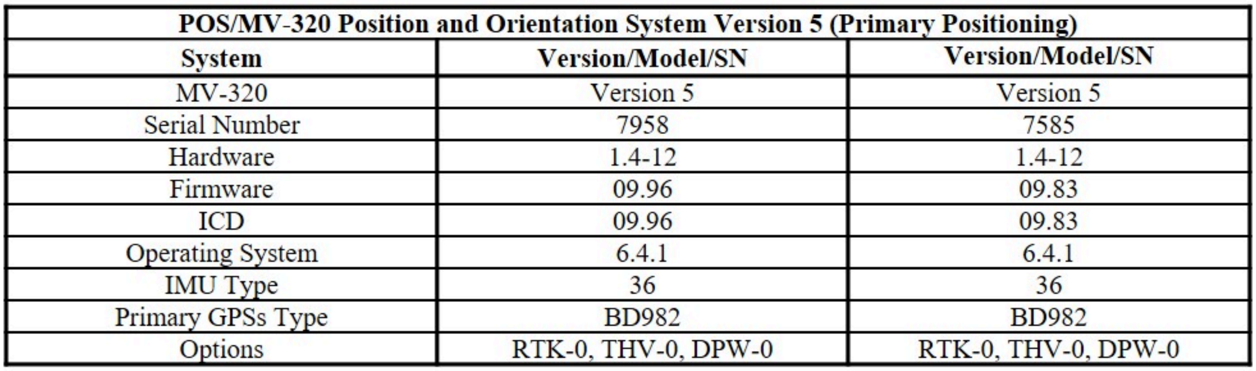
### A.5.1.1 Applanix POS/MV-320 Position and Orientation System Version 5

The Applanix POS/MV-320 Position and Orientation System Version 5 was used as the primary positioning and attitude sensor. POS/MV is a GNSS-aided inertial positioning and orientation system designed to provide georeferencing and motion compensation solutions to hydrographic survey platforms. The system is comprised of a rack-mounted POS Computer system (PCS) unit, an Inertial Measurement Unit (IMU), and two GNSS antennas. On the M/V Atlantic Surveyor, the port antenna was configured as the primary and the starboard antenna, as secondary. Refer to the table below and Figure 2 for the POS/MV system details.

A GPS Azimuth Measurement System (GAMS) calibration was conducted on 2019-04-05 (JD 095), which confirmed the Baseline Vector values from the sensor dimensional offset survey, which was conducted on 2019-01-31. Refer to the Appendices of this Report for the calibration and configuration reports.

Shortly after the start of OPR-K371-KR-19 survey operations, the POS/MV real-time solution indicated issues with the USCG DGPS RTCM correction messages. While no issues were observed in post-processing of the corresponding navigation data, on 2019-05-01 (JD 121), the POS/MV PCS in use (S/N 7958) was replaced with PCS (S/N 7585) in order to confirm the solution across independent hardware. When the same results were observed with both PCS units, as well as the secondary C-Nav system, the issue was confirmed to be resulting from the USCG DGPS RTCM data and likely related to the locality of the survey area compared to the available USCG DGPS stations, and the planned phase out of these stations in the coming year. Based on these results the POS/MV was then configured for use of the Wide Area Augmentation System (WAAS) for the real-time navigation solution. All post-processed navigation data used for application to final survey data were fully reviewed and found to meet all accuracy and quality standards. Details on both PCS units are captured in the Table below; refer to Section A.5.2 and Section C.3.1.2 for further details on the use of DGPS over the course of survey operations.

<table>
<tr><td><i>Manufacturer</i></td><td>Applanix</td></tr>
<tr><td><i>Model</i></td><td>POS/MV-320 Position and Orientation System Version 5</td></tr>
<tr><td><i>Inventory</i></td><td>
<table>
<tr><td><i>Component</i></td><td>IMU</td><td>PCS</td><td>PCS</td><td>Antenna</td><td>Antenna</td></tr>
<tr><td><i>Model Number</i></td><td>IMU36</td><td>MV-320 Version 5</td><td>MV-320 Version 5</td><td>GA830</td><td>GA830</td></tr>
<tr><td><i>Serial Number</i></td><td>3308</td><td>7958</td><td>7585</td><td>11307</td><td>10177</td></tr>
<tr><td><i>Calibration</i></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
</td></tr>
</table>



**POS/MV-320 Position and Orientation System Version 5 (Primary Positioning)**

| System | Version/Model/SN | Version/Model/SN |
|---|---|---|
| MV-320 | Version 5 | Version 5 |
| Serial Number | 7958 | 7585 |
| Hardware | 1.4-12 | 1.4-12 |
| Firmware | 09.96 | 09.83 |
| ICD | 09.96 | 09.83 |
| Operating System | 6.4.1 | 6.4.1 |
| IMU Type | 36 | 36 |
| Primary GPSs Type | BD982 | BD982 |
| Options | RTK-0, THV-0, DPW-0 | RTK-0, THV-0, DPW-0 |

*Figure 2: POS/MV Systems*

### A.5.2 DGPS

#### A.5.2.1 Trimble Differential Receivers

DGPS Receivers were used to provide USCG corrections to the POS/MV and/or C-Nav units during acquisition. A Trimble ProBeacon differential receiver was configured for USCG DGPS input to the POS/MV system and a Trimble SPS356 GNSS Beacon Receiver was configured for USCG DGPS input to the C-Nav system. Both DGPS units were programmed to lock into appropriate USCG stations for the survey area, either English Turn, LA (Station Frequency 293kHz) or Angleton, TX (Station Frequency 301kHz). Periodic checks were made to confirm the correct DPGS stations were in use. Refer to Section C.3.1.2 for further details on the use of DGPS over the course of survey operations.

<table>
<tr><td><i>Manufacturer</i></td><td>Trimble</td></tr>
<tr><td><i>Model</i></td><td>Differential Receivers</td></tr>
<tr><td><i>Inventory</i></td><td><table><tr><td></td><td><table>
<tr><td><i>Component</i></td><td>DGPS Receiver</td><td>DGPS Receiver</td></tr>
<tr><td><i>Model Number</i></td><td>ProBeacon</td><td>SPS356</td></tr>
<tr><td><i>Serial Number</i></td><td>0220186953</td><td>5527R35049</td></tr>
<tr><td><i>Calibration</i></td><td></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.5.3 GPS

#### A.5.3.1 Oceaneering C-Nav 3050

An Oceaneering C-Nav 3050 Global Positioning System (GPS) Receiver was configured as a secondary positioning sensor and used for real-time QC of the primary (POS/MV) positioning systems. During acquisition, real-time differences in the positioning solution between the POS/MV and C-Nav units were periodically checked for discrepancies. Raw observables from the C-Nav unit were recorded for use in the event that issues were observed during processing of primary positioning data.

<table>
<tr><td><i>Manufacturer</i></td><td>Oceaneering</td></tr>
<tr><td><i>Model</i></td><td>C-Nav 3050</td></tr>
<tr><td><i>Inventory</i></td><td><table><tr><td></td><td><table>
<tr><td><i>Component</i></td><td>C-NAV</td></tr>
<tr><td><i>Model Number</i></td><td>3050</td></tr>
<tr><td><i>Serial Number</i></td><td>23469</td></tr>
<tr><td><i>Calibration</i></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

## A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

## A.6 Sound Speed Equipment

### A.6.1 Moving Vessel Profilers

### A.6.1.1 AML Oceanographic MVP30

A MVP30, originally manufactured by Brooke Ocean and now a part of AML Oceanographic, along with an AML Oceanographic MVPX, which is compatible with suite of interchangeable Sound Velocity (SV), Pressure (P), and Temperature (T) Xchange sensors, were the primary instruments and sensors used to determine sound speed profiles (SSP) for corrections to MBES data. The MVP30 allows for efficient acquisition of underway sound speed profiling. On the M/V Atlantic Surveyor, the MVP30 was mounted on the starboard stern quarter of the vessel. The system consists of a deck unit, configured with an Electrical winch, control box, and overboard sheave. The deck unit is powered and interfaced to an interior control box and a notebook computer equipped with MVP software for controlling profile acquisition. During survey operations, a MVPX unit, with sound velocity, pressure, and temperature Xchange sensors, is housed in a towbody and is towed by the vessel to allow for regular MVP deployments.

<table>
<tr><td><i>Manufacturer</i></td><td>AML Oceanographic</td></tr>
<tr><td><i>Model</i></td><td>MVP30</td></tr>
<tr><td><i>Inventory</i></td><td><table><tr><td></td><td><table>
<tr><td><i>Component</i></td><td>MVP System</td></tr>
<tr><td><i>Model Number</i></td><td>MVP30</td></tr>
<tr><td><i>Serial Number</i></td><td>10090</td></tr>
<tr><td><i>Calibration</i></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

### A.6.3 Sound Speed Sensors

### A.6.3.1 AML Oceanographic MVP•X

The AML Oceanographic MVP•X instrument, compatible with the AML sound velocity and pressure Xchange sensors noted above, was in use with the MVP30 for primary sound speed profile (SSP) acquisition.

The individual sound velocity, pressure, and temperature Xchange sensors are directly connected to the MVP•X instrument, which is then connected to the MVP30 system via a cable connection in the towbody.

<table>
<tr><td><em>Manufacturer</em></td><td>AML Oceanographic</td></tr>
<tr><td><em>Model</em></td><td>MVP•X</td></tr>
<tr><td><em>Inventory</em></td><td><table><tr><td></td><td><table>
<tr><td><em>Component</em></td><td>Probe</td><td>Probe</td><td>Probe</td></tr>
<tr><td><em>Model Number</em></td><td>MVP•X</td><td>MVP•X</td><td>MVP•X</td></tr>
<tr><td><em>Serial Number</em></td><td>008688</td><td>009032</td><td>009038</td></tr>
<tr><td><em>Calibration</em></td><td></td><td></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.6.3.2 AML Oceanographic Base•X2

AML Oceanographic Base•X2 instruments, compatible with AML sound velocity and pressure Xchange sensors, were maintained onboard the M/V Atlantic Surveyor for the duration of the survey season as a backup to the MVP30. The Base•X2 provides a lightweight and compact form of sound speed profiling technology, allowing for over-the-side hand deployments and wireless transmission of data for expedited cast application. During temporary instances of MVP30 equipment down-time, the Base•X2 instruments were used in the acquisition of sound speed profiles.

<table>
<tr><td><em>Manufacturer</em></td><td>AML Oceanographic</td></tr>
<tr><td><em>Model</em></td><td>Base•X2</td></tr>
<tr><td><em>Inventory</em></td><td><table><tr><td></td><td><table>
<tr><td><em>Component</em></td><td>Probe</td><td>Probe</td></tr>
<tr><td><em>Model Number</em></td><td>Base•X2</td><td>Base•X2</td></tr>
<tr><td><em>Serial Number</em></td><td>025410</td><td>025586</td></tr>
<tr><td><em>Calibration</em></td><td></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.6.3.3 AML Oceanographic MicroX

One AML Oceanographic MicroX SV probe, compatible with the AML SV Xchange sensors noted above, was hull mounted, adjacent to the RESON SeaBat T50 transducer head, in order to allow for real-time application of sound speed.

<table>
<tr><td><em>Manufacturer</em></td><td>AML Oceanographic</td></tr>
<tr><td><em>Model</em></td><td>MicroX</td></tr>
<tr><td><em>Inventory</em></td><td><table><tr><td></td><td><table>
<tr><td><em>Component</em></td><td>Sensor</td></tr>
<tr><td><em>Model Number</em></td><td>MicroX</td></tr>
<tr><td><em>Serial Number</em></td><td>11439</td></tr>
<tr><td><em>Calibration</em></td><td></td></tr>
</table></td></tr></table></td></tr>
</table>

### A.6.3.4 AML Oceanographic SV Xchange

An AML Oceanographic SV Xchange sensor is a field-swappable sound velocity sensor, compatible with the above listed housing units, capable of providing time of flight sound velocity measurements accurate to (+/-) 0.025 m/s.

Refer to the Appendices of this Report for a tabulated list and calibration details of all SV, P, and T Xchange sensors used during OPR-K371-KR-19.

| | |
|---|---|
| *Manufacturer* | AML Oceanographic |
| *Model* | SV Xchange |
| *Inventory* | |

| *Component* | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor | SV Sensor |
|---|---|---|---|---|---|---|---|---|---|---|
| *Model Number* | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange | SV Xchange |
| *Serial Number* | 204453 | 206148 | 206246 | 206249 | 206410 | 206512 | 206513 | 206514 | 206515 | 207191 |
| *Calibration* | 2018-12-04 | 2018-12-06 | 2018-12-06 | 2019-10-31 | 2018-12-06 | 2018-12-06 | 2018-12-06 | 2019-11-19 | 2019-11-19 | 2019-10-30 |

### A.6.3.5 AML Oceanographic P Xchange

An AML Oceanographic P Xchange sensor is a field-swappable pressure sensor, compatible with the above listed housing units, capable of providing pressure measurements accurate to (+/-) 0.05% FS.

Refer to the Appendices of this Report for a tabulated list and calibration details of all SV, P, and T Xchange sensors used during OPR-K371-KR-19.

| | |
|---|---|
| *Manufacturer* | AML Oceanographic |
| *Model* | P Xchange |
| *Inventory* | |

| *Component* | Depth Sensor | Depth Sensor | Depth Sensor | Depth Sensor | Depth Sensor | Depth Sensor | Depth Sensor |
|---|---|---|---|---|---|---|---|
| *Model Number* | P Xchange | P Xchange | P Xchange | P Xchange | P Xchange | P Xchange | P Xchange |
| *Serial Number* | 304601 | 305331 | 305555 | 305557 | 305558 | 305598 | 305840 |
| *Calibration* | 2018-12-19 | 2018-12-19 | 2013-11-01 | 2018-12-19 | 2019-11-25 | 2019-11-20 | 2019-11-01 |

### A.6.3.6 AML Oceanographic T Xchange

An AML Oceanographic T Xchange sensor is a field-swappable temperature sensor, compatible with the above listed housing units, capable of providing temperature measurements accurate to (+/-) 0.005°C.

Refer to the Appendices of this Report for a tabulated list and calibration details of all SV, P, and T Xchange sensors used during OPR-K371-KR-19.

<table>
<tr><td><em>Manufacturer</em></td><td>AML Oceanographic</td></tr>
<tr><td><em>Model</em></td><td>T Xchange</td></tr>
<tr><td><em>Inventory</em></td><td><table><tr><td></td><td><table>
<tr><td><em>Component</em></td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td></tr>
<tr><td><em>Model Number</em></td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td></tr>
<tr><td><em>Serial Number</em></td><td>404004</td><td>404370</td><td>404395</td><td>404397</td><td>404438</td></tr>
<tr><td><em>Calibration</em></td><td>2018-12-05</td><td>2019-11-19</td><td>2019-11-01</td><td>2019-11-19</td><td>2019-11-01</td></tr>
</table></td></tr></table></td></tr>
</table>

### A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

### A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

### A.7 Computer Software

| *Manufacturer* | *Software Name* | *Version* | *Use* |
|---|---|---|---|
| Leidos | ISS-2000 with Survey Planning | 5.4.0.3.0 | Acquisition |
| Leidos | SABER with Survey Planning | 5.4.0.22.3 | Processing |
| Leidos | iNavLog | 2.7 | Acquisition |
| Klein | SonarPro | 14.0 | Acquisition |
| AML Oceanographic | MVP30 Controller | 2.21 | Acquisition |
| AML Oceanographic | Seacast | 4.3.1 | Acquisition |
| Spectra Precision | Survey Pro Max | 6.1.0.26 | Acquisition |
| Applanix | POS/MV POSView | 9.91 | Acquisition |
| Applanix | POSPac MMS | 8.4 | Processing |
| Trimble | Business Center | 3.90 | Processing |
| SOLIDWORKS | Premium 2018 | SP5.0 | Processing |
| Teledyne CARIS | HIPS and SIPS | 10.4 | Processing |
| ESRI | ArcGIS | 9.3.1 | Processing |
| Jeppesen | dKart Inspector | 6.0 | Processing |
| NOAA | Extended Attribute Files | 5_4 | Processing |
| NOAA and University of New Hampshire (UNH) Center for Coastal Ocean Mapping (CCOM) | Sound Speed Manager | 2019.2.3 | Processing |
| National Aeronautics and Space Administration (NASA) | Panoply | 4 | Processing |
| AutoCAD | Civil 3d | 2018 | Processing |
| AutoCAD | Map 3D | 2011 E.208.0.0 | Processing |
| Altova | XMLSpy | 2020 | Processing |

## A.8 Bottom Sampling Equipment

### A.8.1 Bottom Samplers

#### A.8.1.1 WILDCO Petite Ponar Grab 7128-G40

A Wildco Petite Ponar grab sampler (Figure 3) was used to obtain bottom samples and determine sediment characteristics. The grab sampler is a stainless steel unit with a self-releasing pinch-pin. Additionally, a GoPro Hero4 Camera with a dive light complement, were affixed to the grab sampler by a supplemental metal housing to allow for high-resolution video acquisition in applicable areas. Bottom samples were typically acquired with the grab sampler via a line and block setup through an over-the-side davit.

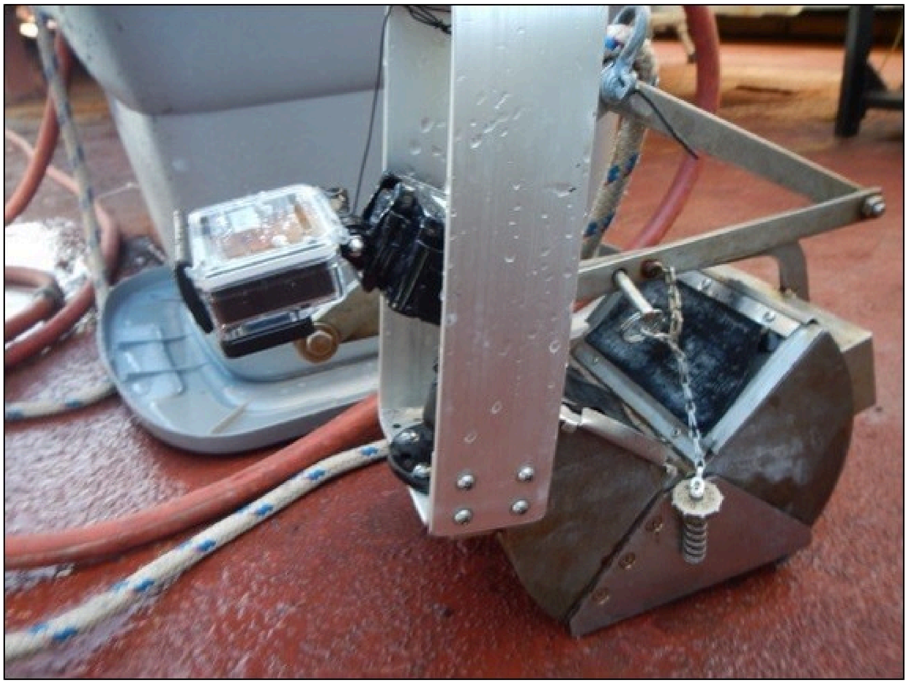


*Figure 3: Bottom Sampler with Camera Attachment*

# B. System Alignment and Accuracy

## B.1 Vessel Offsets and Layback

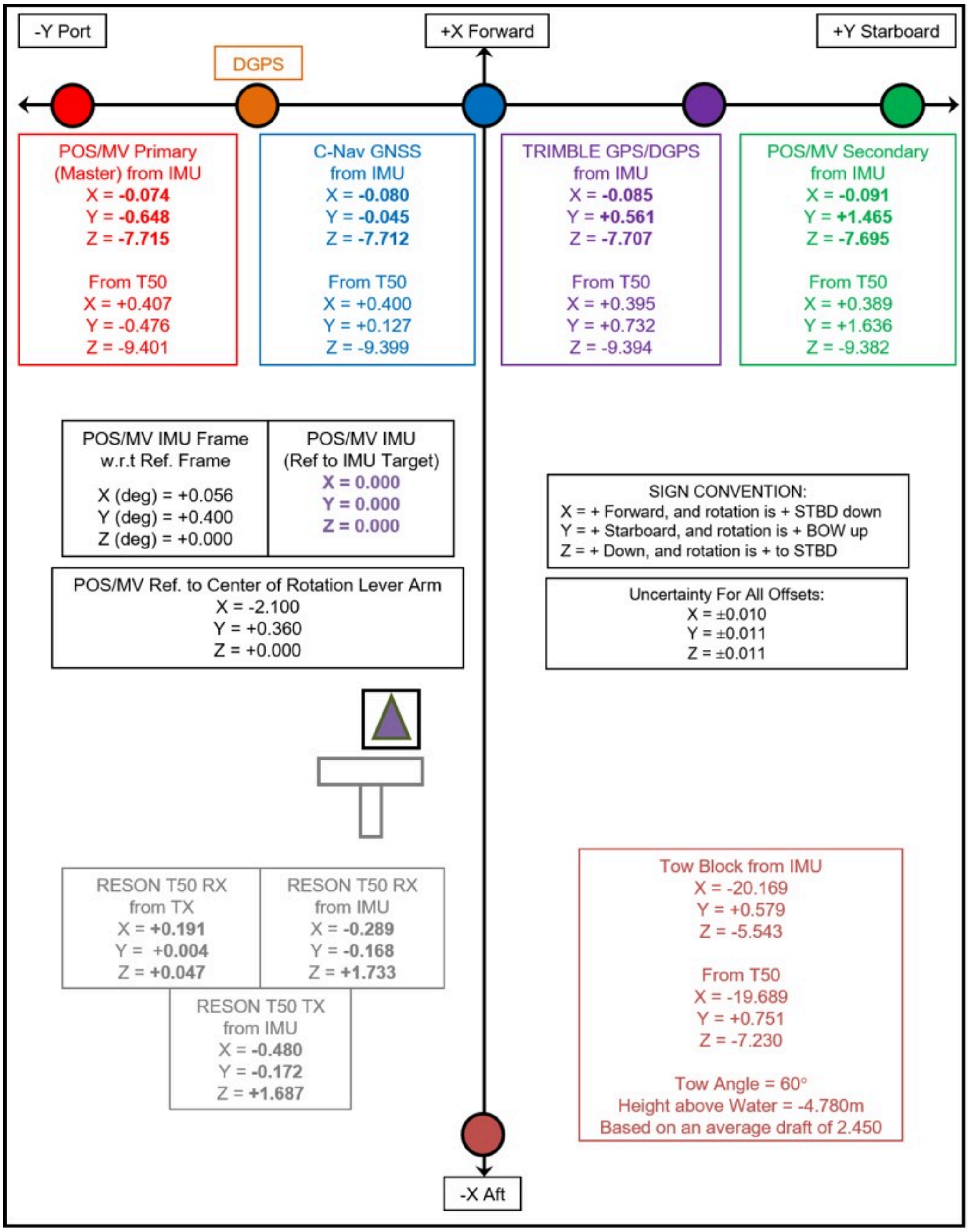
### B.1.1 Vessel Offsets

A static dimensional survey of the M/V Atlantic Surveyor was conducted in January 2019, whereby the vessel reference frame was determined, as well as installation locations for all hydrographic survey sensors. The POS/MV IMU Target was established as the reference point, and all offset measurements were determined using the IMU reference point as the vessel reference point.

The RESON SeaBat T50 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 MBES system's transducer array, and both the navigation and heave were translated to this location of the MBES system through the configuration of the POS/MV.

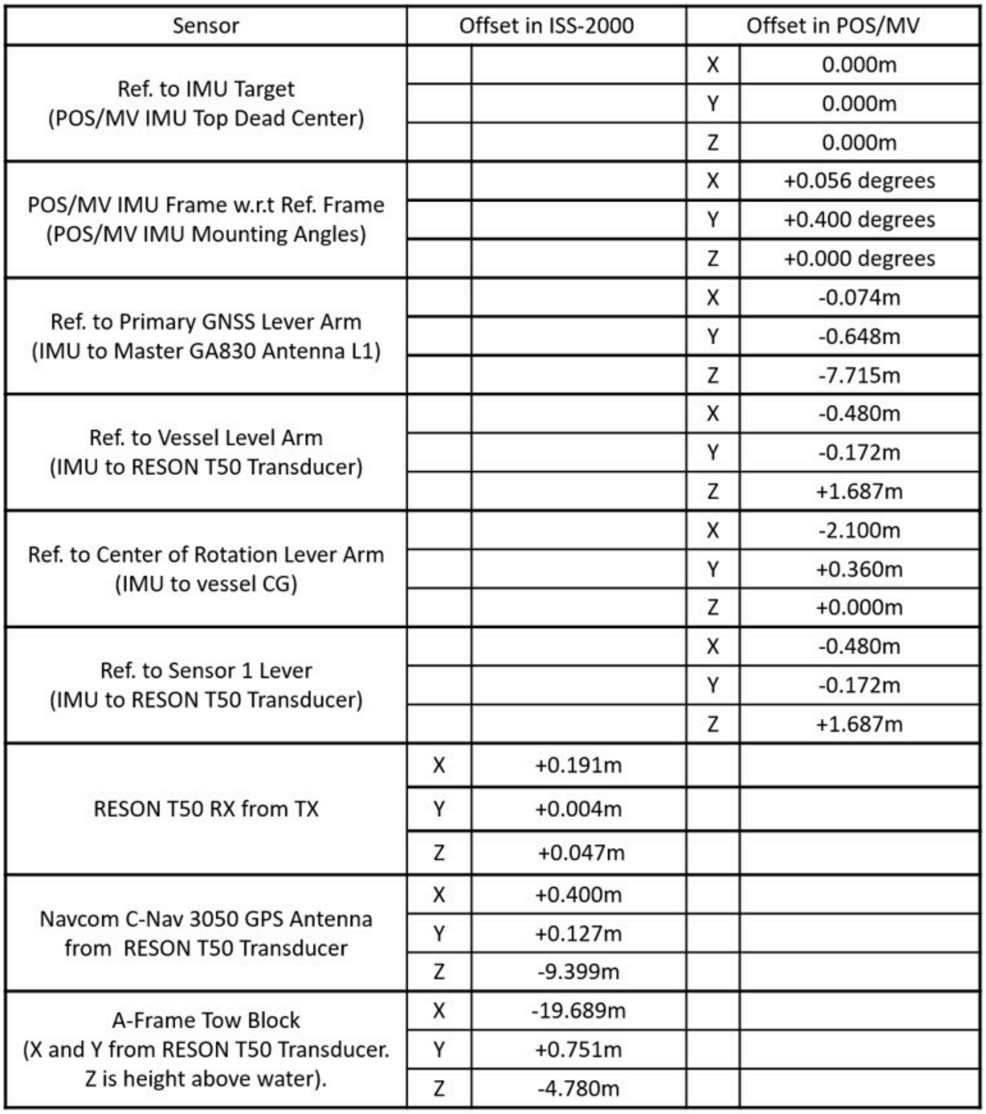
Figure 4 shows the M/V Atlantic Surveyor sensor configuration and the vessel offsets for the RESON SeaBat T50. The 2019 vessel offsets are tabulated in Figure 5 and document sensor offsets that were entered into the POS/MV (offsets referenced to the IMU) or ISS-2000 (offsets referenced to the sonar acoustic center) software. All measurements are in meters and the Leidos ISS-2000 and the POS/MV software utilize a coordinate system where "Z" is defined as positive down, "X" is defined as positive forward, and "Y" is defined as positive to starboard.

Details on the vessel offset survey and results are provided in the DAPR Appendices.



**2019 Configuration and Offsets of *M/V Atlantic Surveyor* Sensors for the RESON T50**
**(Measurements in Meters with 1-Sigma Uncertainty)**

*Figure 4: Configuration and Offsets of M/V Atlantic Surveyor Sensors (Measurements in Meters with 1-Sigma Uncertainty)*



| Sensor | Offset in ISS-2000 | | Offset in POS/MV | |
|---|---|---|---|---|
| Ref. to IMU Target (POS/MV IMU Top Dead Center) | | | X | 0.000m |
| | | | Y | 0.000m |
| | | | Z | 0.000m |
| POS/MV IMU Frame w.r.t Ref. Frame (POS/MV IMU Mounting Angles) | | | X | +0.056 degrees |
| | | | Y | +0.400 degrees |
| | | | Z | +0.000 degrees |
| Ref. to Primary GNSS Lever Arm (IMU to Master GA830 Antenna L1) | | | X | -0.074m |
| | | | Y | -0.648m |
| | | | Z | -7.715m |
| Ref. to Vessel Level Arm (IMU to RESON T50 Transducer) | | | X | -0.480m |
| | | | Y | -0.172m |
| | | | Z | +1.687m |
| Ref. to Center of Rotation Lever Arm (IMU to vessel CG) | | | X | -2.100m |
| | | | Y | +0.360m |
| | | | Z | +0.000m |
| Ref. to Sensor 1 Lever (IMU to RESON T50 Transducer) | | | X | -0.480m |
| | | | Y | -0.172m |
| | | | Z | +1.687m |
| RESON T50 RX from TX | X | +0.191m | | |
| | Y | +0.004m | | |
| | Z | +0.047m | | |
| Navcom C-Nav 3050 GPS Antenna from RESON T50 Transducer | X | +0.400m | | |
| | Y | +0.127m | | |
| | Z | -9.399m | | |
| A-Frame Tow Block (X and Y from RESON T50 Transducer. Z is height above water). | X | -19.689m | | |
| | Y | +0.751m | | |
| | Z | -4.780m | | |

*Figure 5: M/V Atlantic Surveyor Offsets (Measurements in Meters with 1-Sigma Uncertainty)*

### B.1.1.1 Vessel Offset Correctors

| | | | | |
|---|---|---|---|---|
| *Vessel* | M/V Atlantic Surveyor | | | |
| *Echosounder* | Reson Seabat T50 | | | |
| *Date* | 2019-01-31 | | | |
| *Offsets* | | | *Measurement* | *Uncertainty* |
| | *MRU to Transducer* | *x* | -0.480 meters | 0.010 meters |
| | | *y* | -0.172 meters | 0.011 meters |
| | | *z* | 1.687 meters | 0.011 meters |
| | *Nav to Transducer* | *x* | -0.480 meters | 0.010 meters |
| | | *y* | -0.172 meters | 0.011 meters |
| | | *z* | 1.687 meters | 0.011 meters |
| | *Transducer Roll* | *Roll* | 0.00 degrees | |

### B.1.2 Layback

The M/V Atlantic Surveyor side scan towfish positioning was provided by ISS-2000 through a Catenary program that used cable payout and towfish depth in meters 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 sensor), the towfish depth (sent via a serial interface from the side scan sonar (SSS) system to ISS-2000), and the Course Made Good (CMG) of the vessel. See the DAPR Appendices for the vessel layback diagram. The calculated towfish position was sent to the SSS system via the TowfishNav 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 SSS data file in real-time during data acquisition. A remote winch controller inside the data acquisition ISO (International Organization for Standards) container allowed for cable adjustments to maintain acceptable SSS towfish altitudes and sonar record quality. Changes to the amount of cable out were automatically saved to the ISS-2000 message and payout files.

Refer to the DAPR Appendices for a layback diagram and the vessel layback report from SAT verifications.

### B.1.2.1 Layback Correctors

<table>
<tr><td><em>Vessel</em></td><td>M/V Atlantic Surveyor</td></tr>
<tr><td><em>Echosounder</em></td><td>Klein 3000</td></tr>
<tr><td><em>Frequency</em></td><td>100 kHz</td></tr>
<tr><td><em>Date</em></td><td>2019-01-31</td></tr>
<tr><td><em>Layback</em></td><td><table>
<tr><td><em>Towpoint</em></td><td><table>
<tr><td><em>x</em></td><td>-19.689 meters</td></tr>
<tr><td><em>y</em></td><td>0.751 meters</td></tr>
<tr><td><em>z</em></td><td>-4.780 meters</td></tr>
</table></td></tr>
<tr><td><em>Layback Error</em></td><td>0.011 meters</td></tr>
</table></td></tr>
<tr><td><em>Frequency</em></td><td>500 kHz</td></tr>
<tr><td><em>Date</em></td><td>2019-01-31</td></tr>
<tr><td><em>Layback</em></td><td><table>
<tr><td><em>Towpoint</em></td><td><table>
<tr><td><em>x</em></td><td>-19.689 meters</td></tr>
<tr><td><em>y</em></td><td>0.751 meters</td></tr>
<tr><td><em>z</em></td><td>-4.780 meters</td></tr>
</table></td></tr>
<tr><td><em>Layback Error</em></td><td>0.011 meters</td></tr>
</table></td></tr>
</table>

## B.2 Static and Dynamic Draft

### B.2.1 Static Draft

The RESON SeaBat T50 transducer was hull-mounted approximately 4.36 meters below the surveyed-in points on the vessel’s main deck port and starboard rails (Figure 6). To determine the draft, a metal draft bar was bolted into the surveyed point on each rail’s draft measurement location so that it extended out far enough to allow a direct measurement to the water line. The distance from the bottom of the metal bar to the water surface was measured and subtracted from the transducer hull depth to determine the draft of the transducer’s acoustic center.

For the M/V Atlantic Surveyor, static draft measurements were taken on each side of the vessel at every port call; both before departure and after arrival, in order to prorate the daily draft accounting for fuel and water consumption. The two draft measurements (port and starboard) and the resulting draft value were recorded in the “Watchstander Logs” 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 Separates I of the DR for each sheet.

An initial processing step of the Leidos data processing pipeline is to apply, if necessary, prorated static draft values to all bathymetric data. This was done to account for the change in the survey vessel draft during consecutive survey days, primarily due to fuel and water consumption.

For a given period of survey, the change in vessel static draft divided by the number of consecutive days of survey resulted in the amount of change in vessel static draft per day. This daily change in the static draft was then subtracted from the observed static draft value at the beginning of that specific period of survey. This resulted in a unique prorated static draft value for each consecutive survey day that was then applied in post processing to the data for that day. When the JD rollover occurred in the middle of a survey line, the first file of the new day was given the same prorated draft as the previous day. This procedure ensured that the static draft for every survey line was constant and did not cause a vertical jump in the survey depths.

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

The Apply Correctors Offsets tool within SABER was used to apply the calculated prorated draft value to multibeam GSF files as appropriate. This process of applying a new prorated draft offset to the multibeam data was captured within the history record of each multibeam GSF file.

Once prorated static draft had been applied to the multibeam data, the Apply Correctors Offsets tool within SABER was then used to report all the current offsets applied to the data within the multibeam GSF files. This was done to ensure the expected prorated static draft values were correctly applied to all multibeam data.

Table B.2.1.1 below details the first static draft value measurement made for OPR-K371-KR-19. The observed and prorated static draft for each survey is included with the survey data in Separates I of each sheet's DR. The static draft applied to each individual GSF file is reported in the "Multibeam Processing Log" for each sheet.

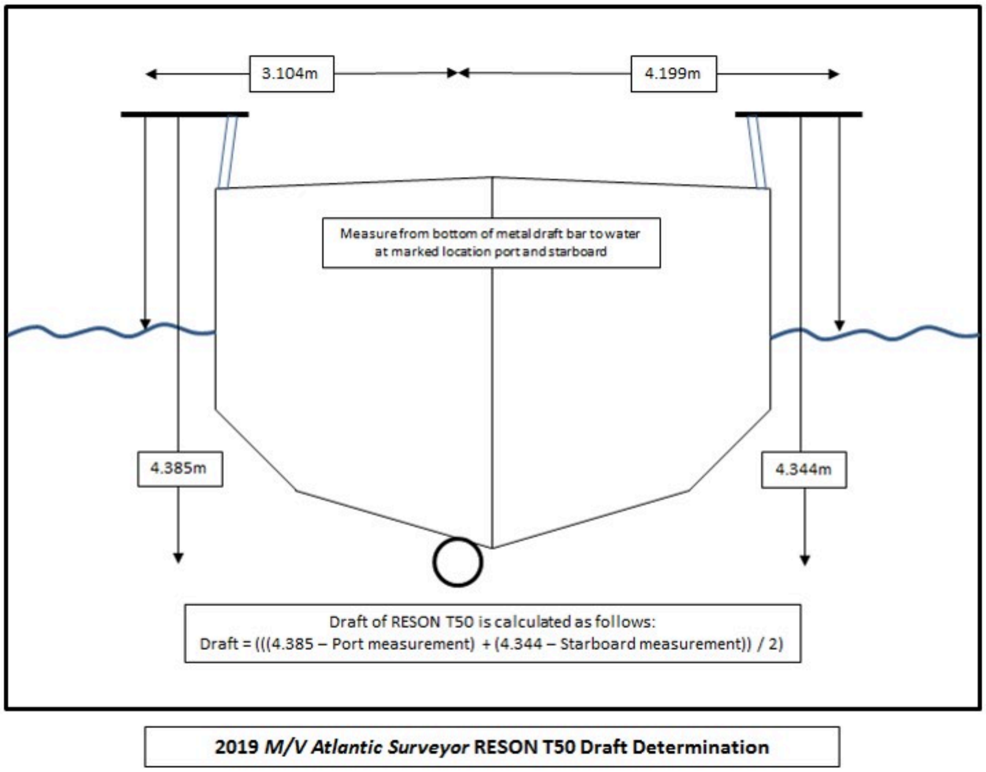


*Figure 6: M/V Atlantic Surveyor RESON SeaBat T50 Draft Determination*

### B.2.1.1 Static Draft Correctors

| | | |
|---|---|---|
| *Vessel* | | M/V Atlantic Surveyor |
| *Date* | | 2019-04-10 |
| *Loading* | | 0.02 meters |
| *Static Draft* | *Measurement* | 2.38 meters |
| | *Uncertainty* | 0.01 meters |

### B.2.2 Dynamic Draft

The M/V Atlantic Surveyor was fitted with two RPM sensors, which provided port and starboard main engine shaft RPM data to ISS-2000. RPM data were logged while the automatic input was simultaneously used in conjunction with the settlement and squat look-up table in the ISS-2000 vessel configuration file. The combination of the real-time engine shaft RPM data and the settlement and squat look-up table, allowed for the application of a continuously updated dynamic draft value to the MBES data during acquisition.

All dynamic draft corrections applied to MBES data by ISS-2000 were to a precision of 0.01 meters, below the allowable 0.05-meter precision as defined in Section 5.2.3.2 of the HSSD.

To support the look-up table in the ISS-2000 vessel configuration file used for dynamic draft application, settlement and squat values to the nearest centimeter have been determined for the M/V Atlantic Surveyor during independent SAT operations for over ten years, with very little variation from year to year. A running average of historical settlement and squat values was determined, as shown the DAPR Appendices, and used as the baseline for the 2019 SAT settlement and squat determination.

Data acquisition during the process to determine the settlement and squat correctors for each individual SAT was completed using an ISS-2000 vessel configuration file that had all settlement and squat look-up table values zeroed out. This allowed for an independent determination of baseline values during each SAT performed.

During each individual SAT of the M/V Atlantic Surveyor an initial depth reference surface was created by stopping the vessel and acquiring MBES data as the vessel drifted with the prevailing winds and current. A survey transect was then established crossing perpendicular to the reference surface. While acquiring MBES data, this transect was run at least twice (once in each direction) with individual shaft RPM settings per pair of lines run, and for each of the shaft RPM settings as listed in the DAPR Appendices.

Separate 0.5-meter CUBE PFM grids were then created from the MBES data using the near nadir (±10 degrees) beams collected for the drift reference line and for each of the RPM pairs. Individual difference grids were created comparing the CUBE depth layer of the reference drift line PFM grid and the CUBE depth layer of each RPM pair PFM grid. The resulting difference grids were then analyzed using SABER's Frequency Distribution Tool. This tool allowed the hydrographer to determine the distribution of depth differences between each RPM pair and the reference drift line. The delta for each pair of RPM lines was computed, as shown in the DAPR Appendices.

The newly computed values were then entered into a running average spreadsheet. For the 2019 SAT, this running average spreadsheet consisted of historical settlement and squat data from eleven previous years. The newly computed settelment and squat values were then averaged with the historical data to determine updated values for each of the RPM settings. These results were analyzed for the agreement of the newly computed values to the historical and average data, and to ensure the standard deviation of all results was within the allowable 0.05-meter precision as defined in Section 5.2.3.2 of the HSSD.

After analysis, the 2019 SAT settlement and squat determination values, and resulting new running average values, were deemed satisfactory. The new running average values were entered into the ISS-2000 vessel configuration file used for all data acquisition of OPR-K371-KR-19. The settlement and squat results for the M/V Atlantic Surveyor are shown in the DAPR Appendices.

The Dynamic Draft uncertainty value is captured as an input to the overall Error Parameters File (EPF) used in ISS-2000 for application of Total Propagated Uncertainty (TPU) during real-time data acquisition and in SABER during data processing. See Section B.2 of this Report for details of the Uncertainty Model and EPF. The Dynamic Draft uncertainty value used as an input to the EPF was determined by taking the maximum standard deviation value from each calculation within the running average spreadsheet (0.03m for M/V Atlantic Surveyor SAT 2019), and then rounding up to the nearest half decimeter (0.05m). This rounding to the nearest half decimeter was done to be more conservative, as well as to match the allowable 0.05-meter precision as defined in Section 5.2.3.2 of the HSSD.

Note that the Table in B.2.2.1 below references units of “Speed (m/s)” due to the available XML schema options. As described above Leidos applies dynamic draft correctors based on measured shaft RPM data, and the values listed in the Table B.2.2.1 are RPM values.

### B.2.2.1 Dynamic Draft Correctors

| | | |
|---|---|---|
| *Vessel* | M/V Atlantic Surveyor | |
| *Date* | 2019-04-10 | |
| *Dynamic Draft* | *Speed (m/s)* | *Draft (m)* |
| | 140.00 | 0.01 |
| | 180.00 | 0.02 |
| | 250.00 | 0.04 |
| | 300.00 | 0.06 |
| | 340.00 | 0.09 |
| | 380.00 | 0.11 |
| *Uncertainty* | *Vessel Speed (m/s)* | *Delta Draft (m)* |
| | 0.00 | 0.05 |

## B.3 System Alignment

### B.3.1 System Alignment Methods and Procedures

A Sea Acceptance Test (SAT) was conducted prior to the start data acquisition on this project. For additional details and results on SAT operations conducted refer to the Appendices of this Report.

SAT operations included at least, but were not limited to, the following:
- Ping timing test to verify that no timing errors existed within the survey system
- POS/MV GAMS Calibration Verification
- Multibeam patch test to determine bias values for roll, pitch, and heading
- Dynamic Draft determination and verification
- Beam-by-beam analysis of the multibeam data performed with the SABER ACCUTEST program
- Small survey to analyze multibeam accuracies after the installations.
- Multibeam lead line comparison.

Navigation positioning, heading, heave, roll, and pitch were provided by the Applanix POS/MV 320 version 5, IMU36, Inertial Navigation. Resolution and accuracy of the systems 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

Leidos has developed a timing test procedure to evaluate the entire survey acquisition system for any timing errors, which was conducted during SAT. This test demonstrated that all RESON SeaBat T50 ping times collected by ISS-2000, as logged GSF data files, matched the corresponding ping trigger event recorded from the RESON sonar processor. This further demonstrated that the overall timing of the complete data acquisition system, as controlled from the POS/MV navigation system, the NTP server, and ISS-2000, was within acceptable accuracy thresholds. The timing test procedure and the results are discussed in detail within the DAPR Appendices.

As previously noted in Section A.5.1.1, Leidos conducted a GAMS calibration 2019-04-05. Refer to the Appendices of this Report for further information on GAMS.

Leidos' Patch Test (Alignment) has been developed for the determination of system biases for roll, pitch, and heading (gyro/yaw). For each type of bias, multiple comparisons were made to assure the most accurate results.

Data were also collected from the same lines after the biases were entered into the acquisition system to verify their accuracy. All alignment data files were processed in SABER using standard post processing procedures, such as removing noise and applying delayed heave prior to bias determination.

A roll bias results in a cross-track vertical and small horizontal displacement. The roll bias test compared the depths from two lines of MBES data collected on the same transect run in opposite directions over a relatively flat, smooth bottom. The lines were run in pairs, at least two times in reciprocal directions at the same speed for each pair. The SABER Swath Alignment Tool was then used to further analyze the data and compare the across track beams over the flat smooth bottom in order to determine a final roll bias value.

A pitch bias results in an along-track horizontal and small vertical displacement. The pitch bias test compared the depths from two lines of MBES data collected on the same transect run in opposite directions perpendicular to a smooth sloping bottom or over a distinct feature. The lines were run in pairs, at least two times in reciprocal directions at the same speed for each pair. The SABER Swath Alignment Tool was then used to further analyze the data and compare the along track, near nadir beams over the bottom slope or distinct feature in order to determine a final pitch bias value.

A heading bias results in a cross-track horizontal displacement. The heading bias test compared the depths from two MBES lines collected on two separate transects run in opposite directions over a distinct feature or perpendicular to a slope. The two separate transects were spaced to achieve approximately 50% overlap in the MBES swath from each line. The lines were at least collected four times, running each line in opposite directions at same speed and then re-running each line in the reciprocal direction at the same speed. The SABER Swath Alignment Tool was then used to further analyze the data and compare the along track overlapping beams over the distinct feature or perpendicular to a slope to determine a final heading bias value.

Roll, pitch, and heading biases were determined on 2019-04-06 (JD 096) for the RESON SeaBat T50 installed on the M/V Atlantic Surveyor. After the installation of the replacement RESON SeaBat T50, alignments were confirmed on 2019-08-10 (JD 222) (refer to the Appendices for details).

After bias values were determined and confirmed as final, they were entered into the ISS-2000 configuration file used for data acquisition and applied in real-time to all bathymetry data acquired.

Dynamic draft determination and verification is discussed in Section B.2.2.

Leidos has developed standard procedures as part of the SAT to confirm that the multibeam system accuracies meet all applicable specifications and quality standards. Examples of these procedures conducted during each SAT include the SABER ACCUTEST, as well as the performance of a mini survey.

The SABER ACCUTEST procedure performs a detailed beam-to-beam analysis of the multibeam data. For this test, two orthogonal survey lines were established and each line was run at the same speed multiple times in each direction. A CUBE PFM grid of the ±10 degrees near-nadir beams was generated. Every beam across the entire swath of each ping was compared to the referenced CUBE Depth surface created with the near nadir beams. The results are presented in the Appendices of this Report.

The mini survey procedure mirrors the efforts that would be conducted on a full scale survey project to provide an end to end test of all acquisition and data processing systems to demonstrate the system capability and functionality while operating in survey mode. Typically, these mini surveys are performed over a feature and surrounding area. Following data acquisition, standard processing procedures are followed to evaluate the data against all applicable specifications and quality standards. The data processing routine followed the pipeline as detailed in the flow diagram provided within the Appendices of this Report. The mini survey results are also presented in the Appendices of this Report. All results showed that the systems met the accuracy and uncertainty standards stated in Section 5.1.3 of the HSSD.

Lead line comparisons were conducted to provide Quality Assurance (QA) for the RESON SeaBat T50 onboard the M/V Atlantic Surveyor as specified within Section 5.2.3.1 of the HSSD. Lead line comparison confidence checks were performed as outlined in the following steps:
1. The static draft of the survey vessel was measured immediately prior to the beginning of the comparison. The value was entered into the ISS-2000 real-time parameters for the multibeam (see Section B.2.1 of this Report for a detailed description of static draft).
2. Correctors to the multibeam data, such as predicted tides and dynamic draft, were disabled in the ISS-2000 system; ISS-2000 is enabled to log MBES data.
3. A sound speed profile was taken and applied to the multibeam data in ISS-2000.
4. A timekeeping device was synchronized to the time of the ISS-2000 data acquisition system in order to accurately record the time for each lead line depth observation made.
5. Ten lead line depth measurements were acquired on each side of the vessel at the location of the multibeam transducer.
6. The current JD, date, vessel draft value, the multibeam data file(s), and the sound speed profile file were entered in the "Lead Line Comparison Log" (Separates I for each sheet).
7. The observed time and depth of each lead line measurement were entered in the "Lead Line Comparison Log".
8. The concurrent multibeam depth measurements recorded in the GSF file were then entered in the "Lead Line Comparison Log".

Lead line depth measurements were made using a mushroom anchor affixed to a line and a tape measure (centimeter resolution). The measurements taken provide the distance from the seafloor to a surveyed-in point on both the port and starboard rails. At least ten separate depth measurements and corresponding times were recorded for both the port and starboard sides. The measurements were recorded into the spreadsheet which uses the static draft measurement to calculate the water depth.

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

#### B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td colspan="3">M/V Atlantic Surveyor</td></tr>
<tr><td>Echosounder</td><td colspan="3">Reson Seabat T50</td></tr>
<tr><td>Date</td><td colspan="3">2019-04-10</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
<tr><td>Pitch</td><td>0.570 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.390 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>3.100 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.000 seconds</td></tr>
</table>

# C. Data Acquisition and Processing

## C.1 Bathymetry

### C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Central to the Leidos survey system was the Integrated Survey System Computer (ISSC). The ISSC consisted of a dual 8 core processor computer with the Windows 7 (Service Pack 1) operating system, which ran the Leidos Integrated Survey System 2000 (ISS-2000) software. In addition to data acquisition and logging for bathymetry, backscatter, and navigation data, this software provided survey planning, real- time survey control, and real-time Quality Control (QC). An Applanix POS/MV and IMU were used to provide positioning, heave, and vessel motion data during these surveys.

Data acquisition was carried out using the Leidos ISS-2000 with Survey Planning software (Section A.7) for Windows 7 operating systems to control data acquisition, navigation, data time tagging, and data logging.

Leidos maintains the ability to decrease the usable MBES swath width for the RESON systems as necessary to maintain data quality and meet the required IHO specifications. Specifics of RESON settings in use during acquisition are discussed in Section A.2.1.1. During MBES data collection ISS-2000 applied beam flags to the GSF, designating the swath data as either Class 1 or Class 2 based on the acquired swath beam angle and user set parameters in ISS-2000.

Onboard the M/V Atlantic Surveyor with the RESON SeaBat T50, the Class 1 parameter was set to ±5 degrees in ISS-2000, which applied the Class 1 beam flag to the acquired swath 10 degrees about nadir. Class 2 was then set to 90 degrees, which applied the Class 2 beam flag to all acquired swath data from 5 degrees per side of nadir to the maximum achieved swath beam angle. Within the Sonar UI controller of the RESON SeaBat T50, the maximum coverage angle was then manually set to 120 degrees (60 degrees per side). Swath data flagged as Class 1 or Class 2 were used for grid generation while data outside of Class 2 were flagged as ignore (but were retained for potential future use). Class 1 data were used for grid generation of cross line data used in junction analysis (see Section D.1.5 for details). As noted in Section C.2.1, Leidos collected MBES backscatter within all GSF data acquired.

For all sheets, Leidos chose to achieve the Complete Coverage requirement outlined in the PI using Option B, 100% side scan sonar coverage with concurrent multibeam bathymetry collection with complete coverage multibeam developments of contacts and features. The resultant achievable MBES bottom coverage was controlled by set survey line spacing and the various water depths within the survey areas. The survey line spacing was 130 meters for use with a SSS range of 75 meters, 80 meters line spacing for use with a SSS range setting of 50 meters, or 40 meters line spacing for use with a SSS range setting of 25 meters. Using ±60 degrees as the acceptable swath, 100 percent MBES coverage was not achieved in all areas, nor was it required by the PI.

All MBES data and associated metadata were collected and stored on the real-time survey computer (ISSC) using a dual logging architecture. This method ensured a copy of all real-time data files were logged to separate hard drives during the survey operations. On the M/V Atlantic Surveyor, these files were archived to the on-board NAS for initial processing and QC review at the completion of each survey line.

The Leidos naming convention of MBES GSF files has been established through ISS-2000. To provide specific identification of the survey vessel, year, Julian Day (JD) that the data file was collected, and time that the file was created. For example in MBES file “asmba19114_123235.gsf”:

- “as” refers to survey vessel M/V Atlantic Surveyor
- 19114 refers to the year (2019) and JD (114)
- 123235 refers to the time (HHMMSS) the file was created

File names were generally changed at the end of each line. This protocol provided the ability to easily associate each consecutive MBES GSF file with a specific survey line. Occasionally, when surveying holiday fills and/or item investigations, groups of multiple survey lines of the same type were collected to the same GSF file. If a file was not manually changed between a mainscheme and crossline, the MBES GSF file was split during post processing. This procedure utilized the SABER command line program gsfsplit. This program provided the ability to split GSF files so that each survey line was unique to a single MBES GSF file or set of files. In all cases, mainscheme and crossline data were delivered in separate GSF files.

When a MBES file needed to be split, a copy of the original GSF file was made and the gsfsplit program was then run on the copied file. Using the ping flags stored in the GSF file, gsfsplit splits the file midway through the offline pings between survey lines. Each newly created file resulting from the splitting process was given an extension of “a” and “b”. Once the file split process was complete, the newly created files were manually renamed in the following manner: the first survey line kept the name and time of the original file and each subsequent survey line was assigned a new name based on the time within the file where the split occurred. GSF file lists were updated to include the split files, which were placed in chronological order.

At the end of each survey day all raw real-time data files from the day were backed-up to an external hard drive. All processed data on the field processing computers were backed-up to an external hard drive intermittently throughout the day and by digital magnetic tape approximately every three to five days. The external hard drives and the digital magnetic tape back-ups were shipped approximately every 12-14 days to the Leidos DPC in Newport, RI for further processing and archiving.

Leidos continuously logged MBES data throughout survey operations collecting all data acquired during turns and transits between survey lines. Leidos utilized ping flags within the GSF files to differentiate between online/offline data. Online data refers to the bathymetry data within a GSF file which were used for generating the Combined Uncertainty and Bathymetric Estimator (CUBE) Depth surface. Refer to the Appendices of this Report for a detailed description of MBES ping and beam flags. Information regarding the start and end of online data for each survey line is found in the “Watchstander Logs” and “Side Scan Review Log” that are delivered in Separates I of each sheet’s DR.

Acquisition logs were generated on a daily basis via the Leidos’ iNavLog program, which operates utilizing the MySQL database management system. Leidos defines the MySQL database by sheet. All major data acquisition operations are automatically tracked by iNavLog via a connection to the ISSC. For example, any instance of a multibeam filename change, SSP cast acquisition, SSP cast application, vessel RPM change, survey line acquisition (complete with start time, Survey Line ID, current multibeam filename, and RPM and ship azimuth at the start of the line), and survey line end time, will be automatically entered into the MySQL database by sheet. Additionally, iNavLog allows for manual user entry for all other information pertinent to the survey. Watchstanders are able to annotate the survey line acquisition note to include the side scan filename in use and whether or not the survey line being run is a mainscheme, crossline, item, or holiday line. The watchstanders may also populate notes specific to multibeam and side scan data acquisition, such as start of operations, side scan sonar and range scale in use, and weather entries. The program is setup for the watchstander to be able to generate an acquisition log per Julian Day, which is then output to an Excel spreadsheet. Acquisition logs are reviewed on a daily basis and are compiled per each sheet’s deliverable in Separates I, Acquisition and Processing Logs.

Data Processing Methods and Procedures

Post processing was performed on the survey vessel M/V Atlantic Surveyor and in the Newport, RI, Data Processing Center (DPC). MBES and SSS data were processed and reviewed on computers with the Linux operating system, which ran Leidos' SABER (Survey Analysis and Area Based Editor) software. Onboard the M/V Atlantic Surveyor and in the Newport, RI DPC, data were stored on a Network Attached Storage (NAS) system that all computers were able to access.

Survey planning, data processing, and analysis were carried out using the Leidos SABER with Survey Planning software for Linux operating systems. Periodic upgrades were installed in the Newport, RI DPC and on the survey vessel M/V Atlantic Surveyor.

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 commenced.

Onboard the M/V Atlantic Surveyor, the MBES data were then reviewed in Leidos SABER's MultiView Editor (MVE) program to flag erroneous data such as noise, flyers or fish, and to designate features or designated soundings. MVE is a geo-referenced editor, which can project each beam in its true geographic position and depth in both plan and profile views. Positions and depths of features were determined directly from the bathymetry data in the Leidos MVE swath editor by flagging the least depth on the object. A bathymetry feature file (CNT) was created using the SABER Feature/Designated File from GSF routine. The CNT file contains the position, depth, type of feature, and attributes extracted from the flagged features in the MBES data.

One of the initial processing steps, along with reviewing and editing the data, was to apply delayed heave to the GSF files. The process to apply delayed heave uses the Applanix TrueHeave™ (.thv) files (for further detail refer to Section C.4). Leidos refers to TrueHeave™ as delayed heave. Next, TPU values were computed for each beam in the GSF files before they were loaded into a PFM CUBE surface (refer to Section C.1.4.1 for details on CUBE surface generation). 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.

Leidos generated smoothed best estimate of trajectory (SBET) files through Applanix POSPac MMS software; the SBET data were then applied to the multibeam data through SABER's MergeNav program (refer to Section C.4).

Following the application of corrected navigation, the MBES data were corrected for water levels using the VDatum separation model through SABER's Apply GPSZ program. For additional details refer to Section C.3.2.1. The final TPU for each beam was then calculated and applied to the bathymetry data.

See the DAPR Appendices for a detailed data processing flow diagram.

### C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

### C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

### C.1.4 Gridding and Surface Generation

#### C.1.4.1 Surface Generation Overview

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

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

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

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

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

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

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

Addition of a sounding to a node starts by insertion of the sounding's depth, vertical uncertainty, and propagated variance into a node-based queue structure. Each node has a queue where soundings are written prior to calculation of a hypothesis. The queue is used to delay the impact of outliers on the hypothesis.

Currently, the queue limit within SABER is 11 soundings. CUBE will not calculate a depth hypothesis for a node until all available soundings have entered the queue or there are at least 11 soundings in that node's queue.

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

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

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

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

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

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

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

SABER has incorporated CUBE processing into the PFM layer structure. As an option when building a PFM layer, the user can choose to run the CUBE process which adds a series of additional surfaces to the PFM layer:
- CUBE Depth, which contains the depth value from the node’s best hypothesis (unless there is an over-ride).
- Node Shoal Depth, which contains the shoalest depth of the soundings in the chosen CUBE hypothesis.
- Node Number of Hypotheses, which shows the number of hypotheses that were generated for each node.
- Hypothesis Standard Deviation, which shows the CUBE algorithm’s calculated depth uncertainty for the best hypothesis of a node. This is reported at the CI selected by the user during the PFM build process (95% CI for all surveys). This is simply a measure of how well the soundings that made up a hypothesis compare to each other. It is not a measure of how good the soundings are.
- Node Hypothesis Strength, which shows a node-by-node estimate for how strongly supported a hypothesis depth estimate is. This value is calculated as follows: a ratio of the number of samples in the “best” hypothesis and the samples in the next “best” hypothesis is generated. The ratio is subtracted from an arbitrary limit of 5. The hypothesis strength is interpreted as the closer this value is to zero, the stronger the hypothesis. If the resulting product is less than zero, it will be reported as a zero.
- Hypothesis Number of Soundings, which reports the number of soundings that were used to calculate the best hypothesis.
- Hypothesis Average TPU, is a second uncertainty value calculated by SABER, not the CUBE algorithm. This value is computed by taking the average of the vertical component of the TPU for each sounding that contributed to the best hypothesis for the node. It provides an alternative method for describing the likely depth uncertainty for nodes. The average TPU value does provide a measure of how good the soundings are that made up the hypothesis.
- Hypothesis Final Uncertainty, this surface is populated with the greater value of the Hypothesis Standard Deviation and the Hypothesis Average TPU surfaces.

Once built, the different PFM surfaces were displayed, analyzed, and edited using SABER. All PFM surfaces were used throughout the data processing stages to aid in analysis, interpretation, and editing of the survey data, as well as for QA/QC tools to ensure specifications of the HSSD were met. When all survey data were finalized, Leidos built a final PFM using the CUBE option. Then Leidos converted the PFM grid to a Bathymetric Attributed Grid (BAG).

One of the key requirements for Navigation Surfaces, and hence for BAG layers, is that all depth values have an associated uncertainty estimate and that these values must be co-located in a gridded model, which provides the best estimate of the bottom. To meet this requirement Leidos has implemented a combined CUBE/BAG approach in SABER. In this approach, SABER creates BAG layers by converting the CUBE Depth surface, the associated Hypothesis Final Uncertainty surface, and optionally several other surfaces of a PFM grid to a BAG, as outlined in HSSD Section 5.2.1.

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

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

In addition to the depth and uncertainty surfaces, other child layers can also be converted to the BAG. These surfaces have been grouped with the BAG file structure.

The Elevation Solution Group is made up of the following three surfaces:
- shoal elevation - the elevation value of the least-depth measurement selected from the sub-set of measurements that contributed to the elevation solution.
- number of soundings - the number of elevation measurements selected from the sub-set of measurements that contributed to the elevation solution.
- stddev - the standard deviation computed from all elevation values which contributed to any hypothesis within the node. Note that the stddev value is computed from all measurements contributing to the node, whereas shoal elevation and number of soundings relate only to the chosen elevation solution.

The Node Group is made up of the following two surfaces:
- hypothesis strength - the CUBE computed strength of the chosen hypothesis
- number of hypotheses - the CUBE computed number of hypotheses

For OPR-K371-KR-19 all BAG files were generated with the Corrector surface populated with the VDatum gridded through SABER (OPR-K371-KR-19_NAD83_VDatum_MLLW.cov).

The SABER Convert PFM to BAG utility populates each layer of the BAG from the corresponding layer of the CUBE PFM and maintains the PFM grid resolution. The final delivered BAG files for this project are version 1.5.1, uncompressed, and include both the Elevation Solution Group surfaces and the Node Group surfaces. Note that a maximum size of each BAG file was 4 GB, which may result in more than one BAG file being delivered for a sheet.

Each generated BAG file also has a separate extensible markup language (XML) metadata file that SABER created as the BAG was generated. The xml metadata file is populated with the UTM projection, bounding coordinates, horizontal datum, node spacing, the responsible party, name of the dataset, person responsible for input data, and other information specific to the project and survey sheet.

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

### C.1.4.2 Depth Derivation

Leidos utilizes all of the surfaces available within the PFM structure to assess data quality and identify features within the multibeam data. Using the CUBE surfaces as well as the bathymetry points, the multibeam data are assessed to invalidate soundings not consistent with the general bathymetric profile, which are deemed to be outliers, as well as to identify navigationally significant features. Hydrographers may set features within the PFM grid, in accordance with Section 5.2.1.2.3 of the HSSD.

An initial pass of area based editing review was performed using MVE on the CUBE PFM grid, including review of the grid's various layers, such as the minimum and maximum filtered depth layers and the Hyp. Final Uncertainty layer. Any edits performed will then be unloaded back to the GSF files. On these CUBE PFM grids, the SABER Check PFM Uncertainty routine and the SABER Gapchecker routine are both run. Leidos reviews the results from both of these programs to assess for any remaining outliers and identify coverage gaps. Leidos repeats this analysis until data review is determined to be final.

### C.1.4.3 Surface Computation Algorithm

For each survey sheet, all bathymetry data were processed into a one-meter node PFM CUBE surface, in accordance with Section 5.2.2.2 of the HSSD, for analysis using SABER and MVE. The PFM CUBE surface was generated to demonstrate coverage for the entire sheet. All soundings used in development of the final CUBE depth surface had modeled vertical and horizontal uncertainty values at or below the allowable maximum uncertainty as specified in Section 5.1.3 of the HSSD.

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

After creation of the initial PFM CUBE surfaces, the SABER Check PFM Uncertainty function was used to highlight all of the cases where computed final node uncertainties exceeded IHO Order 1a. These nodes were investigated individually and typically highlighted areas where additional cleaning was necessary. Nodes found in the final PFM CUBE grid that still exceed uncertainty are addressed in the DR for each sheet.

When all GSF files and the PFM CUBE surface were determined to be satisfactory, the PFM CUBE grid was converted to BAG file(s) for final delivery.

## C.2 Imagery

### C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

In accordance with the HSSD, Leidos collected MBES backscatter with all GSF data acquired. The MBES settings were checked to ensure acceptable quality standards were met and to mitigate any acoustic saturation of the backscatter data. The MBES backscatter data acquired were written to the GSF in real-time by ISS-2000 and are delivered in the final GSF files for each sheet.

Data Processing Methods and Procedures

Per HSSD Section 6.2.1, as the Project Instructions did not state to evaluate the backscatter data; backscatter data were not processed by Leidos and no additional products were produced.

### C.2.2 Side Scan Sonar

Data Acquisition Methods and Procedures

SSS data were acquired using the Klein SonarPro software running on the Leidos Side Scan Acquisition computer (SS-ACQ) which also consisted of a dual 8 core processor computer with the Windows 7 (Service Pack 1) operating system. The SS-ACQ was integrated with the ISSC for timing and navigation.

Survey operations were conducted at set line spacing optimized to achieve 100% SSS coverage. During survey operations, 16-Bit digital data from the TPU were acquired, displayed, and logged by the Leidos SS-ACQ through the use of Klein's SonarPro software, which supported SSS data acquisition, side scan system control, logging of SSS data, and real-time QC. Raw digital SSS data were collected in extended Triton format (XTF) and maintained at full resolution, with no conversion or down sampling techniques applied. SSS data file names were changed automatically after 180 minutes or manually at the completion of a survey line, whichever occurred first.

These XTF files were archived at the completion of each survey line, to the on-board NAS, for initial processing and QC. At the beginning of each survey day the raw XTF SSS data files from the previous day were backed up to an external hard drive attached directly to the SS-ACQ machine. All processed SSS data on the NAS were backed up to an external hard drive daily and digital magnetic tape approximately every three to five days. The external hard drive and the digital magnetic tape back-ups were shipped to the DPC in Newport, RI, during port calls.

The Leidos naming convention of side scan XTF data files has been established through the structure of Klein's SonarPro software to provide specific identification of the survey vessel ("as" for the M/V Atlantic Surveyor), JD that the data file was collected, calendar date, and time that the file was created. For example in side scan file "as114_190424121700.xtf":

- "as" refers to survey vessel M/V Atlantic Surveyor.
- 114 refers to JD 114.
- 190424 refers to the year, month, and day (YYMMDD).
- 1217 refers to the time (HHMM) the file was created.
- 00 refers to a sequential number for files created within the same minute.

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

Leidos utilized a time window file to distinguish between times of online and offline SSS data. Online SSS data refers to the data logged within a SSS XTF file that were used in the generation of the 100% or disproval coverage mosaics. Offline SSS data refers to the data logged within a SSS XTF file which were not used for generating either coverage mosaic.

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

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

The SSS towfish positioning was provided by ISS-2000 through a Catenary program that used cable payout and towfish depth, or cable out and tow angle, 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 MBES system to the tow point (See Appendices of this Report).

The SSS towfish altitude was typically maintained between 8% and 20% of the range scale, in accordance with Section 6.1.2.3 of the HSSD. Additionally, the PI for OPR-K371-KR-19 stated that the towfish altitude was to be maintained no more than two meters below the specified altitude according to Section 6.1.2.3 of the HSSD. In any instance where towfish altitude was lower than the requirements set forth in either the PI or Section 6.1.2.3 of the HSSD, a data gap of the full swath was created or the SABER side scan mosaic generation procedure adjusted the usable SSS swath coverage in accordance with the PI or Section 6.1.2.3 of the HSSD. In instances where the towfish altitude exceeded 20% of the range, Leidos took extra care in reviewing the imagery data to meet all specifications and when required created data gaps of the full swath. Additional splits or holiday lines were run as needed to ensure coverage requirements were met.

Periodic confidence checks on linear features (e.g. trawl scars) or geological features (e.g. sand waves or sediment boundaries) were made during data collection to verify the quality of the SSS data across the full sonar record. These periodic confidence checks were made at least once per survey line when possible; however, they were always made at least once each survey day in accordance with Section 6.1.3.1 of the HSSD.

For these surveys, a K-wing depressor was attached directly to the towed SSS. The use of the K-wing reduced the amount of cable out, which in turn aided positioning accuracy of the towfish and allowed for less inhibited vessel maneuverability. On a few occasions, the K-wing depressor was removed from the towed SSS to allow for more cable-out and a greater distance between the towfish and the vessel prop wash while working in shoal areas.

### Data Processing Methods and Procedures

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

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

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

All SSS data are delivered with completely corrected SSS positions. Towfish track lines were generated by extracting the towfish position at 1-second intervals for QC of the Navup and xtf_io processes.

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

The ACD software used a split-window normalization algorithm commonly referred to as constant false alarm rate (CFAR) detection. In order to avoid thousands of false detections in sand-wave fields, the detection processing included a two-dimensional median wave-number filter to suppress sand waves and other periodic background interference before shadow processing. This process was done using a Detection Parameters File (DPF) input into SABER (Figure 7). A peak and shadow score were calculated independently, and then combined, to produce an overall total contact score. If the overall score was above a defined threshold, then a detection was triggered. This process ran independently on all channels within the XTF file.

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

Once the detections were selected, a Trained Neural Network file was applied to classify the detections as either a contact or clutter (false alarm). For this project, the neural network file used was: Neural_Net_Atlantic_RFH_Gulf_C_Ratio_60A_40R.nnt. This file contained data from four previous NOAA sheets:

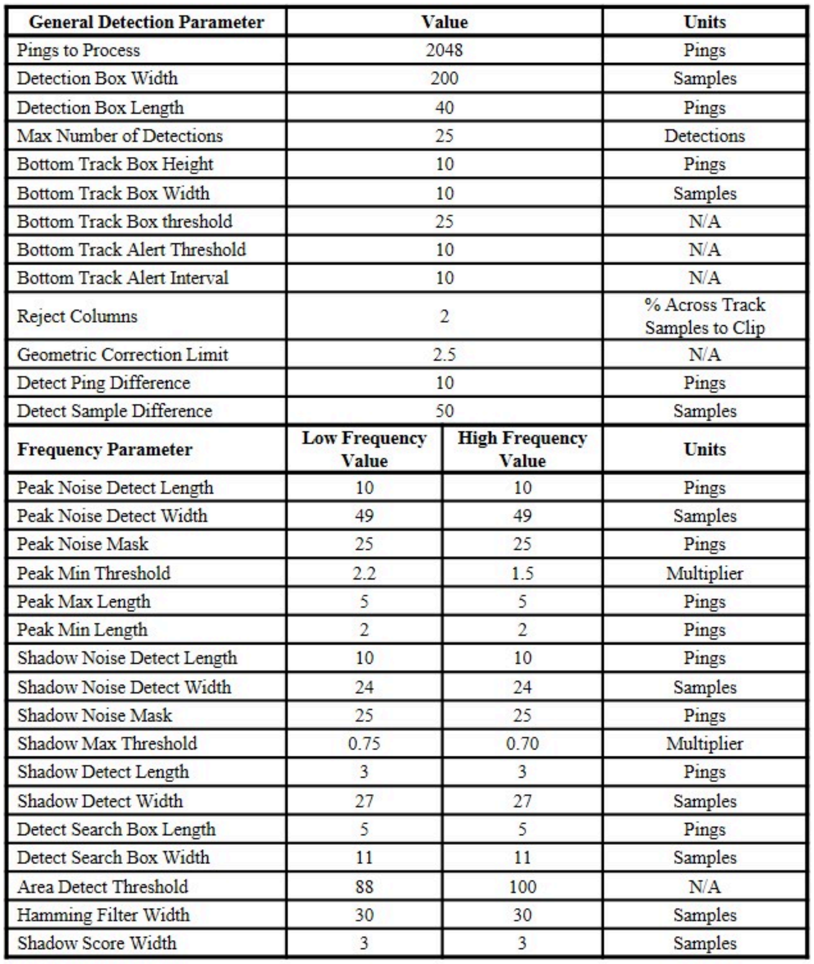
- Sheet F H11241 (2003) Klein 2000
- Sheet H H11455 (2005) Klein 3000
- Sheet R H12094 (2010) Klein 3000
- Sheet C H11785 (2008) Klein 3000

These sheets provided a broad range of data across two sonar types and various bottom types. The Neural Network file was created by taking a random selection of detections from each sheet and creating a ratio of 60 percent accepted detections (true detections) and 40 percent rejected detections (false alarms).

The number of image parameters the Neural Network used was determined by two primary criteria, the Mahalanobis distance (Figure 8) and pair-wise covariance. The Mahalanobis distance is a measure of the statistical distance between two classes based simply on their normal distributions; while the covariance is a measure of how similar the two parameters are. After numerous test cycles 20 parameters were chosen.

When the Trained Neural Network file was applied to the detection files, the program assigned a network activation number to each detection. The network activation number ranged between zero and one, with zero being clutter and one being a contact. For values that fell between zero and one, a user assigned value (decision method) determined which detections were classified as contacts (equal to or greater than the decision method) or as clutter (below decision method). The decision method value used for this project was 0.90, which was determined based on analyzing numerous datasets and decision method values.

See the DAPR Appendices for a detailed data processing flow diagram.



| General Detection Parameter | Value | | Units |
|---|---|---|---|
| Pings to Process | 2048 | | Pings |
| Detection Box Width | 200 | | Samples |
| Detection Box Length | 40 | | Pings |
| Max Number of Detections | 25 | | Detections |
| Bottom Track Box Height | 10 | | Pings |
| Bottom Track Box Width | 10 | | Samples |
| Bottom Track Box threshold | 25 | | N/A |
| Bottom Track Alert Threshold | 10 | | N/A |
| Bottom Track Alert Interval | 10 | | N/A |
| Reject Columns | 2 | | % Across Track Samples to Clip |
| Geometric Correction Limit | 2.5 | | N/A |
| Detect Ping Difference | 10 | | Pings |
| Detect Sample Difference | 50 | | Samples |
| **Frequency Parameter** | **Low Frequency Value** | **High Frequency Value** | **Units** |
| Peak Noise Detect Length | 10 | 10 | Pings |
| Peak Noise Detect Width | 49 | 49 | Samples |
| Peak Noise Mask | 25 | 25 | Pings |
| Peak Min Threshold | 2.2 | 1.5 | Multiplier |
| Peak Max Length | 5 | 5 | Pings |
| Peak Min Length | 2 | 2 | Pings |
| Shadow Noise Detect Length | 10 | 10 | Pings |
| Shadow Noise Detect Width | 24 | 24 | Samples |
| Shadow Noise Mask | 25 | 25 | Pings |
| Shadow Max Threshold | 0.75 | 0.70 | Multiplier |
| Shadow Detect Length | 3 | 3 | Pings |
| Shadow Detect Width | 27 | 27 | Samples |
| Detect Search Box Length | 5 | 5 | Pings |
| Detect Search Box Width | 11 | 11 | Samples |
| Area Detect Threshold | 88 | 100 | N/A |
| Hamming Filter Width | 30 | 30 | Samples |
| Shadow Score Width | 3 | 3 | Samples |

*Figure 7: DPF Used for ACD*

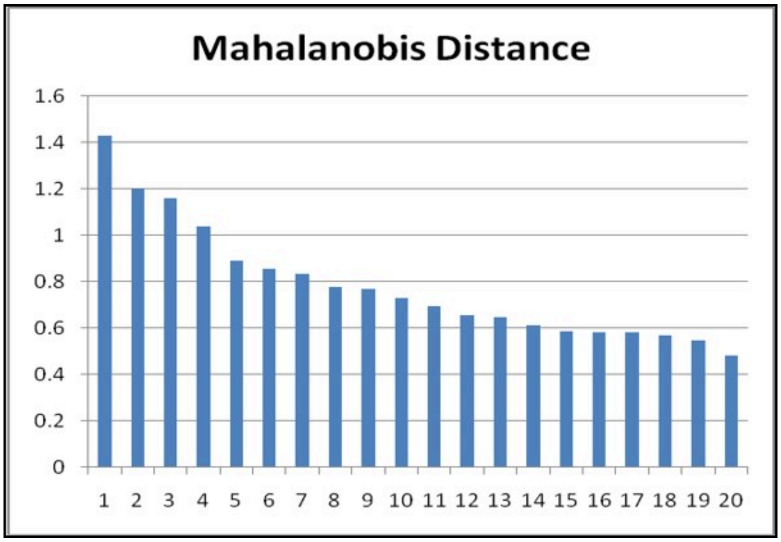


*Figure 8: Mahalanobis Distance of Top Twenty Parameters*

### C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

## C.3 Horizontal and Vertical Control

### C.3.1 Horizontal Control

### C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

### C.3.1.2 DGPS Data

Data Acquisition Methods and Procedures

As noted above in Section A.5, both DGPS units in use (i.e. the Trimble ProBeacon, configured for input to the primary POS/MV positioning system, and the Trimble SPS356, configured for input to the secondary C-Nav positioning system) were programmed to lock into appropriate USCG stations for the survey area, either English Turn, LA or Angleton, TX. Periodic checks were made during acquisition to confirm the correct DPGS stations were in use. Shortly after the start of survey operations in the OPR-K371-KR-19 area, both the POS/MV and C-Nav real-time solutions indicated issues with the USCG DGPS RTCM correction messages. The USCG DGPS Site Configuration Information captures the Angleton, TX Broadcast site as ‘unusable as of 2019-07-09 (JD 190) until further notice.’ On 2019-08-04 (JD 216), English Turn, LA also experienced an outage. At that time, with both DGPS Broadcast Sites experiencing outages, and with the planned discontinuation of all USCG DGPS sites in 2020, a change was made to remove the USCG DGPS inputs to both the POS/MV and C-Nav units and configure the systems to for use of WAAS as the real-time navigation solution. WAAS is a Satellite Based Augmentation System (SBAS) developed by the Federal Aviation Administration (FAA) that provides augmentation information to GPS/WAAS receivers, enhancing the accuracy and integrity of position estimates.

Data Processing Methods and Procedures

DGPS data are not independently processed as part of the normal post processing routine. See Section C.4 for details on post processing of navigation data.

### C.3.2 Vertical Control

#### C.3.2.1 Water Level Data

<u>Data Acquisition Methods and Procedures</u>

During data acquisition, predicted tides were applied through ISS-2000 in real-time. The tidal zoning was provided by the NOAA Center for Operational Oceanographic Products and Services (CO-OPS) and the water level files were downloaded from the CO-OPS Tides &Currents website. The tide data for the project were downloaded, as comma delimited text files (.csv), at 6-minute water level data were in meters, and annotated with the Coordinated Universal Time (UTC). During data acquisition the tide gauge in use was primarily 8770822, Texas Point, Sabine Pass, TX; occasionally, the tide gauge in use was 8771341, Galveston Bay, TX.

At the end of each day, SABER's Check Tides utility was run to confirm that all the multibeam data were corrected with predicted tides prior to continuing with data analysis. Refer to Section C.4 for information regarding the acquisition of navigation data which was used for processing and application of Ellipsoidally Referenced Survey (ERS) water levels.

<u>Data Processing Methods and Procedures</u>

The VDatum separation model was the source of final water level corrections for OPR-K371-KR-19, which reduced the MBES sounding data to MLLW through ERS procedures . The Project Instructions listed that the VDatum separation model was to be used for final data transformation.

After SABER's MergeNav (detailed in Section C.4) process was successful on the multibeam data, the VDatum data were applied through SABER. The SABER Apply GPSZ implementation of VDatum allows for the ping and beam position to be compared against the VDatum data and derives a separation value from ellipsoid to chart datum (NAD83 to MLLW). SABER does not apply VDatum through a surface. The VDatum areas coincident to OPR-K371-KR-19 data were TXlaggal01, TXshlgal01, and LATXwest01 based on correlation of VDatum area to multibeam ping and beam position. Per the PI and additional correspondence with NOAA, VDatum version 3.6.1 was applied.

SABER reads the stored ellipsoidal heights within the GSF record and calculates the difference between the separation model and the ellipsoidal height to generate a GPS tide corrector value. When updated water level correctors were applied to the GSF files, the Apply GPSZ program removed the previous water level correctors and applied the new correctors. Each time the program was run on the GSF files; a history record was appended to the end of the GSF file documenting the date and water level files applied. During SABER's Apply GPSZ the uncertainty from the VDatum was set to a single value as defined in the PI, 12.2 centimeters. The SABER Check Tide Corrections in GSF program was then run on all GSF files to confirm that the appropriate water level corrector had been applied to the final MBES data.

After confirmation that final water levels were applied to all bathymetric data, grids were created and analyzed. In addition, mainscheme to crossline junction analysis was performed using the SABER Frequency

Distribution Tool and the results were analyzed to identify possible depth discrepancies resulting from the applied water level correctors.

As VDatum was used for the final datum transformation, no final tide note was provided from NOAA; however, Leidos provides a final tide note in Appendix I with each sheet's DR.

### C.3.2.2 Optical Level Data

Optical level data was not acquired.

## C.4 Vessel Positioning

Data Acquisition Methods and Procedures

As previously stated in Section C.3.2.1, multibeam data had predicted tides applied in real-time via ISS-2000. In order to correct the multibeam data to be vertically referenced to the ellipsoid, Applanix POS/MV data were logged during acquisition. Logging to the ISSC computer was conducted over a network connection first by the POS/MV POSView software and second through ISS-2000; additionally, data were logged directly to an external USB drive connected to the POS/MV PCS. Data at acquisition were not required to be vertically referenced, as stated in the Supplemental Correspondence (Appendix II of each sheet's DR), however, all final data delivered are vertically referenced to the ellipsoid.

At the start of all survey operations, the Applanix POS/MV was configured to log TrueHeave™ data. As discussed in Section C.1.1, Leidos and SABER use the terminology delayed heave to describe Applanix TrueHeave™ data collected from the Applanix POS/MV. The delayed heave files (.dat) were recorded using ISS-2000 and archived to the NAS in the same manner as GSF files. The delayed heave data were calculated by the Applanix POS/MV based on an algorithm which used a range of temporally bounding Applanix POS/MV real-time heave data to produce a more accurate value of heave. When the resulting delayed heave values were applied to the multibeam data they reduced heave artifacts present from variables such as sea state and survey vessel maneuvering, which are commonly observed in multibeam data with only real-time heave applied.

Data Processing Methods and Procedures

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

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

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

Based on the survey location, Leidos utilized Applanix POSPac MMS software with the Post-Processed Trimble CenterPoint® RTX™ (Trimble PP-RTX) option for all processing of trajectories. Refer to Section A.7 for the software version of POSPac MMS in use for processing. All final solutions applied to the multibeam data were derived from the raw navigation data of the POS/MV. The raw positioning files used to generate final trajectory data are delivered within each sheet's final directory HXXXXX/Raw/Positioning.

The Trimble PP-RTX network is made up of Trimble proprietary base stations, and the Trimble PP-RTX solution is an error model using range and atmospheric corrections, therefore no typical base station Receiver Independent Exchange Format (RINEX) or binary files are produced. Additionally, as all the Trimble proprietary base stations in the network contribute to the solution it is not possible to identify individual stations used for processing each SBET. Therefore, there are no base station data delivered for this project OPR-K371-KR-19.

The Trimble PP-RTX option provides centimeter level post-processed positioning accuracies to the output SBET files. The SBET files were exported from POSPac MMS to NAD83 in an American Standard Code for Information Interchange (ASCII) format text file.

After exporting the SBET files from POSPac MMS, the files were imported into SABER Time-Series Viewer to perform QC and review the trajectory files for spikes. Files were reprocessed in POSPac MMS if spikes were observed in the created SBET.

Following this QC, the SBET trajectories were applied to the MBES data through SABER's MergeNav program. MergeNav replaces the navigation stored in the GSF from data acquisition, and replaces it with the post-processed data from the SBET files. This process also stores the GPS height from the post-processed SBET into the record of each multibeam ping. SABER writes a new H/V Nav Error record into the GSF during this process, which includes information about the source of the updated navigation file (SBET) being applied. SABER supports a least squares interpolation method between ellipsoidal heights. As Leidos processed all OPR-K371-KR-19 with a least squares bracket of 0 seconds; MergeNav utilized a linear interpolation between ellipsoidal heights. The final SBET filename which was applied to the MBES data can be found in the "Multibeam Processing Log" (Separates I) of each sheet's DR.

Final SBET files and the corresponding uncertainty files generated from POSPac MMS are provided within each sheet's HXXXXX/Processing/SBET/ directory.

## C.5 Sound Speed

### C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

An MVP30, with an AML MVPX and Xchange sensors, was the primary means used to collect SSP data. Additionally, AML Base•X2 instruments, also with Xchange sensors, were used to collect SSP data during periods when the MVP30 equipment was not in use. SSP data were obtained at intervals frequent enough to minimize sound speed errors in the MBES data. The frequency of SSP casts was based on the following:

- When the difference between the observed sound speed at the transducer depth in the currently applied SSP exceeded 2 meters per second (m/s) from the real-time observed surface sound speed measured by a sound speed sensor located at the MBES transducer, or measured by the real-time towed data from the MVPX sound speed sensor.
- Time elapsed since the last applied SSP cast.
- When a visible sound speed artifact was observed in the real-time ISS-2000 multibeam bathymetry QA display.

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

The Environmental Manager module in ISS-2000 displayed a real-time time series plot of the sound speed measured at the transducer depth from the currently applied SSP cast and the observed sound speed from the AML MicroX located at the MBES transducer, as well as the calculated difference between these sound speed values. A visual warning was issued to the watchstander when the difference approached and/or exceeded 2 m/s, as defined in Section 5.2.3.3 of the HSSD. Which lead to watchstanders either acquiring new SSP casts or re-applying a previous SSP. During acquisition the application of SSP data are automatically documented within the iNavLog database and are reported within the “Watchstander Log” for each sheet. During the surveys it was not always possible to maintain a difference less than 2 meters/second. This was most apparent on warm sunny days with little or no wind when the solar radiation heated the surface water causing a large change in sound speed near the surface. In all cases attempts were made to take and apply numerous sound speed profiles as needed. Any sound speed related issues will be discussed in each sheet’s DR. Any other environmental factors or occurrences affecting sound speed data, or the ability to meet the 2 m/s requirements of Section 5.2.3.3 of the HSSD, will be documented in the respective sheet’s DR.

During multibeam acquisition, SSP casts were uploaded to ISS-2000 immediately after they were taken. In ISS-2000, the profiles were reviewed for quality, edited as necessary, compared to the preceding casts, and then applied (loaded into the multibeam system for use). Once applied, the multibeam system used the SSP data for depth calculation and ray tracing corrections to the multibeam data. If sounding depths exceeded the cast depth, the ISS-2000 used the deepest sound speed value of the profile to extend the profile to the maximum depth. All MBES data through ISS-2000 are corrected for SSP based on real-time application.

Factors considered in determining how often a SSP cast was needed included shape and proximity of the coastline, sources and proximity of freshwater, seasonal changes, wind, sea state, water depth, observed changes from the previous profiles, and differences in the surface sound speed of the current profile compared to a separate surface sound speed sensor collocated with the multibeam sonar. At a minimum, SSP casts were taken just prior to commencing data acquisition, at intermittent intervals throughout the day during data acquisition (dependent on environmental factors), and immediately following data acquisition.

Confidence checks of the SSP data were periodically conducted (approximately every three to six weeks) by comparing two or more simultaneous or immediately consecutive casts taken with different sound speed sensors. The SSP casts taken during confidence checks were applied to the MBES file being collected in ISS-2000 at that time. The application of the profiles allowed ISS-2000 to maintain a record of each cast. When conducting the SSP comparison casts within the surrounding areas of the survey sheet, one of the comparison cast profiles was commonly applied to the start of the survey line. After downloading the SSP comparison casts, graphs, and tabulated lists were used to compare the corresponding SSP data. Results of the Comparison Cast are presented in each sheet’s DR, Separates II.

Serial numbers and calibration dates are listed in Section A and in the DAPR Appendices for the sensors used to acquire sound speed data for the OPR-K371-KR-19 project. Copies of the calibration records are in the DAPR Appendices. Sound speed data are included with the survey data delivered for each sheet.

### Data Processing Methods and Procedures

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 significant effects due to sound speed profiling could be observed and corrected during real- time data acquisition. Proper sound speed application and effects were also analyzed throughout the survey during post processing in SABER. When necessary, a different SSP file could be applied to MBES data through SABER. During application of the SSP data, SABER performed ray tracing corrections to the multibeam data. The SSP file selected to apply in post-processing was near in time to the MBES ping time, the SABER TPU Model takes into account the age of the sound speed cast in relation to the multibeam data, an older SSP file than multibeam data increases the associated uncertainty. SSP applied for online bathymetry data collection were reviewed to ensure they were acquired within 500 meters of the bounds of the survey area as specified in Section 5.2.3.3 of the HSSD.

All individual SSP files are delivered with the sheet’s data and are broken out into sub-folders, which correspond to the purpose of each cast, listed below. Once all SSP data were determined to be final, the files were concatenated and formatted for use in CARIS are delivered in a separate folder on the delivery drive; “HXXXXX/Processed/SVP/CARIS_SSP”. The CARIS SSP files (.svp) were named based on the designated purpose of the individual SSP casts contained within each of the concatenated files. The purposes were:

- Used for Final Surfaces
- Used for Comparison
- Used for Lead Line
- Used for Closing

For the NCEI sound speed data submission, SSP casts were imported into the NOAA's Sound Speed Manager utility. All individual sound speed profile files were converted to the *.nc file extension and fields were populated with the project, survey, survey unit, and instrument. As with the CARIS SSP data, sound speed data files were broken out into four sub-folders, which correspond to the purpose of each cast. For QC, converted SSP files were reviewed in Panoply. The NCEI sound speed data will be submitted prior to the last sheet of the project.

### C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Collocated to the RESON SeaBat T50 transducer head was an AML Oceanographic MicroX SV probe interfaced with an AML SV Xchange sensor. This unit was integrated with the RESON SeaBat T50 sonar UI to allow for real-time application of surface sound speed. The MicroX unit was integrated with the ISS-2000 system in order to separately log the raw unfiltered sound speed data, should any processing need to be performed at a later date.

During real-time acquisition operations, surface sound speed data from the hull-mounted MicroX unit were monitored through ISS-2000 via the Environmental Manager module, and compared to the surface sound speed from the most recently acquired cast taken by the MVP. This comparison allowed the watchstander to observe when the delta between the two sound speed values exceeded the threshold of two meters/second, specified in Section 5.2.3.3 of the HSSD.

Data Processing Methods and Procedures

The surface sound speed data are not independently processed as part of the normal processing routine however the raw data are logged in the event processing is required and would be discussed in each sheet's DR.

## C.6 Uncertainty

### C.6.1 Total Propagated Uncertainty Computation Methods

The Total Propagated Uncertainty (TPU) model that Leidos has adopted had its genesis at the Naval Oceanographic Office (NAVOCEANO), and is based on the 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 TPU model used by SABER estimates each of the components that contribute to the overall uncertainty that is inherent in each sounding. The model then calculates cumulative system uncertainty (Total Propagated Uncertainty). The data needed to drive the error model were captured as parameters taken from the SABER 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. One of these values was the separation uncertainty; listed in Figure 9 as SEP

Uncertainty. During SABER's Apply GPSZ (detailed in Section C.3.2.1) the uncertainty from the VDatum separation model was inserted into the H/V Nav Error record within the GSF data. When the H/V Nav Error Record is populated with an uncertainty; that value overrides the uncertainty provided in the EPF. Therefore, the multibeam data for OPR-K371-KR-19 had the static value 0.122m utilized when calculating the overall TPU.

While the input units vary, all uncertainty values that contributed to the cumulative TPU estimate were eventually converted to meters by the SABER Calculate Errors in GSF program. The TPU estimates were recorded as the Horizontal Uncertainty and Vertical Uncertainty at the 95% confidence level for each beam in the GSF file. During application of horizontal and vertical uncertainties to the GSF files, individual beams where either the horizontal or vertical uncertainty exceeded the maximum allowable IHO S-44 5th Edition Order 1a specifications were flagged as invalid. As a result, all individual soundings used in development of the final CUBE depth surface had modeled vertical and horizontal uncertainty values at or below the allowable IHO S-44 5th Edition, Order 1a uncertainty. Section C.1.4 describes the CUBE algorithm and Section C.1.4.3 details the uncertainty computations of grid surfaces.

Figure 9 and Figure 10 show the values entered into the SABER EPF used with this project. All parameter uncertainties in this file were entered at the one sigma level of confidence, but the outputs from SABER's Calculate Errors in GSF program are at the two sigma or 95% confidence level. Sign conventions are: X = positive forward, Y = positive starboard, Z = positive down.

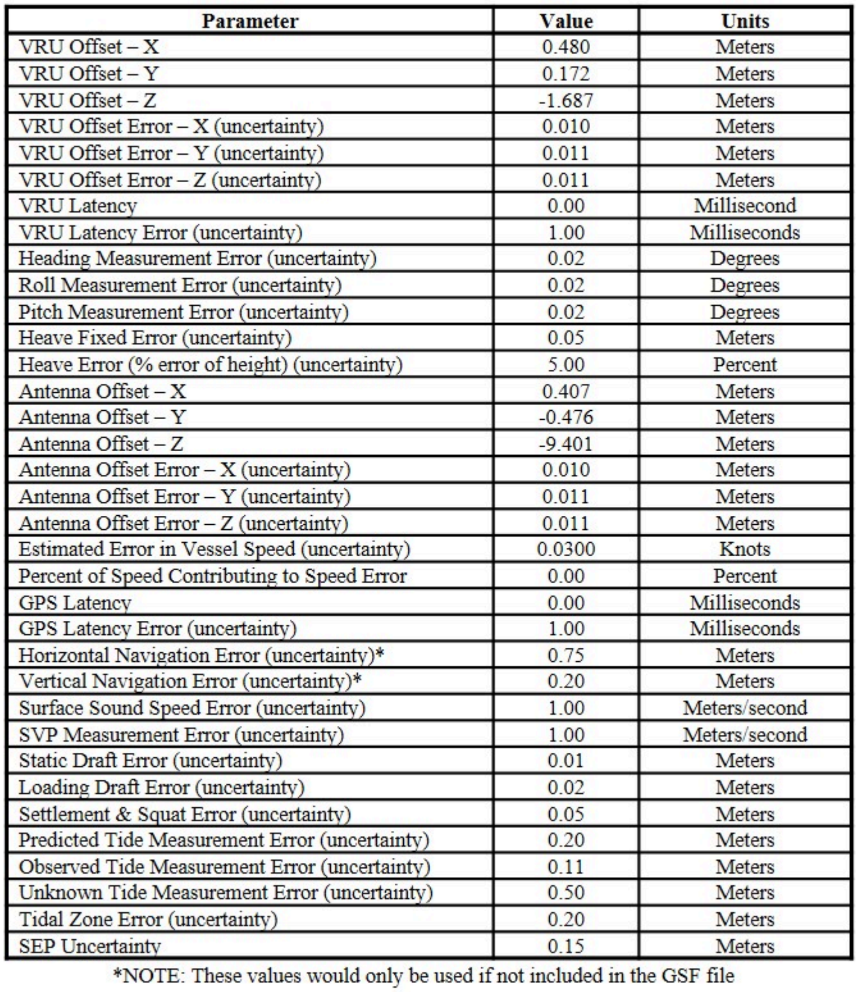
### C.6.2 Uncertainty Components

### A Priori Uncertainty

| *Vessel* | | M/V Atlantic Surveyor |
|---|---|---|
| *Motion Sensor* | *Gyro* | 0.02 degrees |
| | *Heave* | 5.00%<br>0.05 meters |
| | *Roll* | 0.02 degrees |
| | *Pitch* | 0.02 degrees |
| *Navigation Sensor* | | 0.75 meters |

### Real-Time Uncertainty

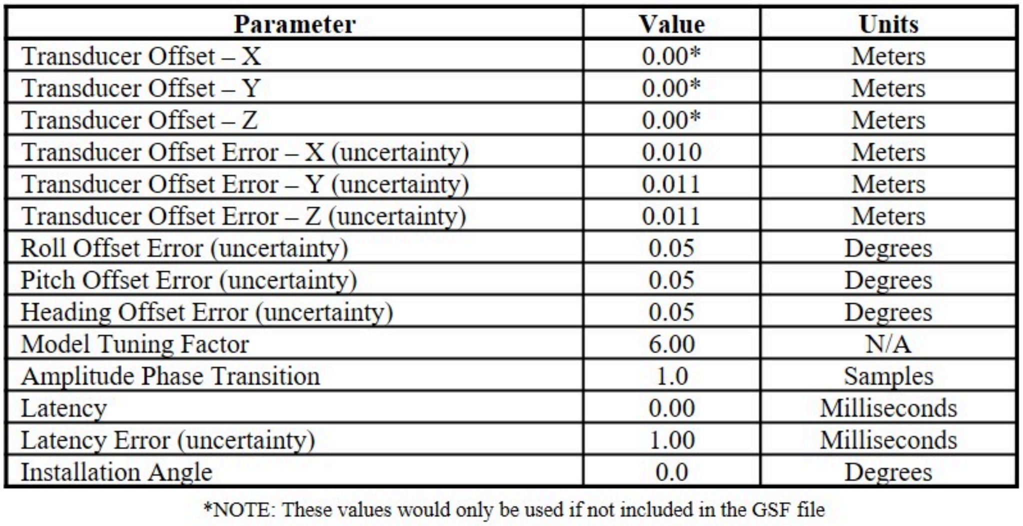
| *Vessel* | *Description* |
|---|---|
| *M/V Atlantic Surveyor* | During real-time data acquisition an Error Parameters File (EPF) within ISS-2000 was used for the application of Total Propagated Uncertainty (TPU) values to the MBES data. As such, the raw bathymetry data, written to Generic Sensor Format (GSF) files, were fully corrected with uncertainties associated with each sounding at the time of acquisition. |



| Parameter | Value | Units |
|---|---|---|
| VRU Offset – X | 0.480 | Meters |
| VRU Offset – Y | 0.172 | Meters |
| VRU Offset – Z | -1.687 | Meters |
| VRU Offset Error – X (uncertainty) | 0.010 | Meters |
| VRU Offset Error – Y (uncertainty) | 0.011 | Meters |
| VRU Offset Error – Z (uncertainty) | 0.011 | Meters |
| VRU Latency | 0.00 | Millisecond |
| VRU Latency Error (uncertainty) | 1.00 | Milliseconds |
| Heading Measurement Error (uncertainty) | 0.02 | Degrees |
| Roll Measurement Error (uncertainty) | 0.02 | Degrees |
| Pitch Measurement Error (uncertainty) | 0.02 | Degrees |
| Heave Fixed Error (uncertainty) | 0.05 | Meters |
| Heave Error (% error of height) (uncertainty) | 5.00 | Percent |
| Antenna Offset – X | 0.407 | Meters |
| Antenna Offset – Y | -0.476 | Meters |
| Antenna Offset – Z | -9.401 | Meters |
| Antenna Offset Error – X (uncertainty) | 0.010 | Meters |
| Antenna Offset Error – Y (uncertainty) | 0.011 | Meters |
| Antenna Offset Error – Z (uncertainty) | 0.011 | Meters |
| Estimated Error in Vessel Speed (uncertainty) | 0.0300 | Knots |
| Percent of Speed Contributing to Speed Error | 0.00 | Percent |
| GPS Latency | 0.00 | Milliseconds |
| GPS Latency Error (uncertainty) | 1.00 | Milliseconds |
| Horizontal Navigation Error (uncertainty)* | 0.75 | Meters |
| Vertical Navigation Error (uncertainty)* | 0.20 | Meters |
| Surface Sound Speed Error (uncertainty) | 1.00 | Meters/second |
| SVP Measurement Error (uncertainty) | 1.00 | Meters/second |
| Static Draft Error (uncertainty) | 0.01 | Meters |
| Loading Draft Error (uncertainty) | 0.02 | Meters |
| Settlement & Squat Error (uncertainty) | 0.05 | Meters |
| Predicted Tide Measurement Error (uncertainty) | 0.20 | Meters |
| Observed Tide Measurement Error (uncertainty) | 0.11 | Meters |
| Unknown Tide Measurement Error (uncertainty) | 0.50 | Meters |
| Tidal Zone Error (uncertainty) | 0.20 | Meters |
| SEP Uncertainty | 0.15 | Meters |

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

*Figure 9: M/V Atlantic Surveyor EPF for the RESON SeaBat T50*



| 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) | 0.010 | Meters |
| Transducer Offset Error – Y (uncertainty) | 0.011 | Meters |
| Transducer Offset Error – Z (uncertainty) | 0.011 | Meters |
| Roll Offset Error (uncertainty) | 0.05 | Degrees |
| Pitch Offset Error (uncertainty) | 0.05 | Degrees |
| Heading Offset Error (uncertainty) | 0.05 | Degrees |
| Model Tuning Factor | 6.00 | N/A |
| Amplitude Phase Transition | 1.0 | Samples |
| Latency | 0.00 | Milliseconds |
| Latency Error (uncertainty) | 1.00 | Milliseconds |
| Installation Angle | 0.0 | Degrees |

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

*Figure 10: M/V Atlantic Surveyor RESON SeaBat T50 Sonar Parameters*

## C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

Shoreline verification was not required for these surveys. Features were set in the multibeam data in accordance with HSSD.

Data Processing Methods and Procedures

Included with each sheet's delivery is an S-57 Feature File made in accordance with the IHO Special Publication No. 57, IHO Transfer Standard for Digital Hydrographic Data, Edition 3.1, (IHO S-57) and Section 7.3 of the HSSD.

The S-57 Feature File was generated through SABER using the SevenCs ECDIS (Electronic Chart Display and Information System) Kernel. The ECDIS Kernel is based on the IHO S-57 as well as the IHO Special Publication S-52 Specifications for Chart Content and Display Aspects of ECDIS (S-52); which details the display and content of digital charts as well as establishing presentation libraries. Leidos implements the SevenCs ECDIS Kernel as a building block, the Kernel maintains the presentation libraries used to create the S-57 Feature Files and retains the IHO requirements, while Leidos maintains the source code which drives the use of the SevenCs ECDIS Kernel so that S-57 Feature Files can be created through SABER.

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

In accordance with Section 7.3.5 of the HSSD, all aids to navigation that fell within the surveyed areas of Project OPR-K371-KR-19 are discussed within the DR for the appropriate sheet and included in the respective sheet's final S-57 Feature File, if necessary.

Feature depths were attributed within the S-57 Feature File as value of sounding (VALSOU) and were maintained to millimeter precision. All features addressed within each sheet were retained within that sheet's respective S-57 Feature File. For all features, the requirements from the IHO S-57 standard were followed, unless otherwise specified in Section 7.3 of the HSSD. Also, following the IHO S-57 standard each sheet's S-57 Feature File is delivered in the WGS84 datum and is unprojected with all units in meters.

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

Each sheet's S-57 Feature File was subjected to ENC validation checks using Jeppesen's dKart Inspector and quality controlled with dKart Inspector and CARIS HIPS & SIPS.

## C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

Bottom characteristics were obtained using a WILDCO Petite Ponar Grab (model number 7128-G40) bottom sampler. The locations for acquiring bottom characteristics were provided in the Project Reference File (PRF) received from the National Oceanic and Atmospheric Administration (NOAA). Unless otherwise noted in each sheet's DR, the position of the bottom sample was not modified from what was provided within the PRF. 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. In addition, Leidos mounted a video camera on the Petite Ponar Grab system, which when possible was used to obtain short videos of the seafloor during the acquisition of assigned sample locations. Photos and videos are delivered, as available, for each sheet on the delivery drive under the folder "HXXXXX/Processed/Multimedia".

Samples were obtained by manually lowering the bottom sampler, with block and line. Each seabed sample was classified using characteristics to quantify color, texture, and particle size.

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

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

Data Processing Methods and Procedures

Bottom characteristics are included within the S-57 Feature File for each sheet, categorized as Seabed Areas (SBDARE) and attributed based on the requirements of the International Hydrographic Organization (IHO) Special Publication No. 57, IHO Transfer Standard for Digital Hydrographic Data, Edition 3.1, (see Section B.2.6 below for details of the S-57 feature file). Digital images of the bottom samples are included in the S-57 Feature File for each sheet, as available.

# D. Data Quality Management

## D.1 Bathymetric Data Integrity and Quality Management

### D.1.1 Directed Editing

Leidos Marine Survey and Engineering Solutions is certified ISO 9001:2015, and has a robust quality system management program, which is, applied to all aspects of our hydrographic survey operations and data deliverables. 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. Several of these documents are included in Separates I of each sheet's DR.

During data acquisition, survey watchstanders continuously monitored the systems, checking for errors and alarms. Thresholds set in the ISS-2000 system parameters alerted the watchstander by displaying alarm messages when error thresholds or tolerances were exceeded. Alarm conditions that may have compromised survey data quality were corrected and noted in both the Watchstander Log and ISS-2000 message files. Warning messages such as the temporary loss of differential GPS, excessive cross track error, or vessel speed approaching the maximum allowable survey speed were addressed by the watchstander and automatically recorded into a message file by ISS-2000. Prior to the start of any survey operations and continuously throughout all survey days, acquisition watchstanders completed checklists to verify critical system settings and ensure valid data collection.

During real-time data acquisition, ISS-2000 applied predicted water level correctors based on the NOAA generated tidal zoning covering the OPR-K371-KR-19 project area, and previously downloaded NOAA predicted tide data from tide stations (8772447 Freeport, TX; 8771341 Galveston Bay, TX; 8770822 Texas Point, Sabine Pass, TX; 8768094 Calcasieu Pass, LA). Also during real-time data acquisition, an Error Parameters File (EPF) within ISS-2000 was used for the application of Total Propagated Uncertainty (TPU) values to the MBES data. As such, the raw bathymetry data, written to Generic Sensor Format (GSF) files, were fully corrected with uncertainties associated with each sounding at the time of acquisition. See Section C.6.1 of this Report for more details of the EPF and Leidos' Uncertainty Model.

Following data collection, initial data processing began onboard the M/V Atlantic Surveyor. This included the first level of QA in SABER; which may include the following:

- Initial swath editing of MBES data flagging invalid pings and beams.
- Application of delayed heave (Applanix TrueHeave™), followed by QC of application.
- Confirmation that the SSP files applied to online data were free of noise and within 500 meters (m) of the survey area.
- QC of MBES predicted tide data application from real-time acquisition
- Computation of Total Propagated Uncertainty (TPU) for each depth value in the MBES data.
- Generation of a preliminary Pure File Magic (PFM) CUBE surface.
- Second review and editing of MBES data using the PFM CUBE surfaces.
- Identify significant features for investigation with additional MBES coverage.
- Turning unacceptable data offline.
- Turning additional data online.
- Identification and flagging of significant features and designated soundings.
- Generation of MBES and SSS track line plots.
- Preliminary minimum sounding grids.
- Perform junction analysis (mainscheme depth data to crossline depth data)

- Running SSS data through the SABER Automatic Contact Detection (ACD) program.
- Application of Trained Neural Network to flag false alarms in SSS detections.
- Hydrographer review of SSS imagery data.
- Hydrographer review of SSS contact files.
- Adjustments to SSS time windows based on data quality.
- Generation of preliminary SSS coverage mosaics.
- Identification of holidays in the SSS coverage.

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

- Mainscheme, item, and holiday fill survey lines (full swath data).
- Crosslines using only near-nadir (±5 degrees, Class 1) data.

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

Approximately once every two weeks backups of all raw and processed survey data were sent to the Leidos DPC in Newport, RI.

Final analysis of the data included at least the following steps:

- Verification of SSS contact files.
- Application of prorated draft to multibeam data.
- Generation of SBET data through Applanix POSPac MMS software.
- Application of SBET data to the multibeam data through SABER's MergeNav.
- Application of VDatum separation model as water level correctors to multibeam data.
- Computation of TPU for each depth value in the MBES data.
- Generation of a one-meter CUBE PFM surface for analysis of coverage, areas with high TPU, and features.
- Perform junction analysis comparing mainscheme depth data to crossline depth data, through surface difference review
- Perform junction analysis comparing the current sheet to prior and/or current sheets.
- Generation of final CUBE PFM surface (one-meter or two-meter).
- Comparison with existing charts.
- QC review of SSS data and contacts.
- Generation of final coverage mosaics of SSS data.
- Correlation of SSS contacts with MBES features and/or designated soundings.
- Generation of S-57 feature files.
- Generation of final Bathymetric Attributed Grid(s) (BAG) and metadata products.
- Final QC of all delivered data products.

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

### D.1.2 Designated Sounding Selection

Within the Generic Sensor Format (GSF) structure, separate flags exist for a designated sounding and a feature. During data analysis, Leidos set designated soundings or feature flags to help better preserve the shoalest sounding relative to the computed depth surface, in accordance with the HSSD. All depths flagged as a feature or designated sounding override the CUBE best estimate of the depth in the CUBE PFM grid; these overrides are carried through to the final generated BAG files. Both the designated sounding and feature flags, as defined within GSF, are mapped to the same HDCS flag when ingested into CARIS (PD_DEPTH_DESIGNATED_MASK). Refer to the Appendices of this Report for an outline of GSF to CARIS ping and beam flag code mapping. Feature specific information is delivered within each sheet's Final Feature S-57 file.

### D.1.3 Holiday Identification

Bathymetric coverage analysis was conducted during initial data processing and on the final CUBE surface to identify areas where (if any) data coverage holidays existed. As previously stated in Section C.1.1, these survey operations were conducted with line spacing optimized to achieve 100% side scan sonar coverage.

The SABER Gapchecker utility was run on the CUBE surface to identify and flag any areas of data holidays exceeding the allowable three by three nodes. In addition, the entire surface was visually scanned for holidays. Before closing out field operations, additional survey lines were run to fill any holidays detected. Results of the bathymetry coverage analysis are presented in each sheet's DR.

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

### D.1.4 Uncertainty Assessment

Refer to Section C.1.4 for details regarding Leidos' uncertainty attributions in CUBE and Section C.6.1 for details regarding Leidos' Uncertainty Model and EPF for TPU attribution specific to soundings. The data submitted are fully corrected with uncertainties associated with each sounding. Therefore, the CARIS vessel file will be all zeros.

### D.1.5 Surface Difference Review

#### D.1.5.1 Crossline to Mainscheme

A beam-to-beam comparison of crossline data to mainscheme data was not performed. Leidos instead conducted junction analysis on a difference surface by subtracting one grid from a separate reference grid to create a depth difference grid. During data acquisition, comparisons of mainscheme (±60 degrees, Class 2) to crossline near-nadir (±5 degrees, Class 1) 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 mainscheme and crossline data that were acquired during the survey. Crosslines were acquired at varying time periods throughout the survey period so that the crossline analyses could provide an indication of any potential temporal or systematic issues (if any) that may affect the data. The mainscheme grid was subtracted from the crossline grid, therefore a positive depth difference would indicate that the crossline data are deeper than the mainscheme data, and a negative depth difference would indicate that the crossline data are shoaler than the mainscheme data. The SABER Frequency Distribution Tool was used on the resulting depth difference grid for the junction analysis and statistics. The number count and percentage of depth difference values resulting from the Frequency Distribution Tool were calculated and reported four ways; as a total of all difference values populating the cells of the difference grid, as the amount of positive difference values populating the cells of the difference grid, as the amount of negative difference values populating the cells of the difference grid, and as the amount of values populating the cells of the difference grid which resulted in a zero difference. This was used to provide an analysis of the repeatability of the multibeam data system. A frequency distribution could not only be run on the overall resulting difference grid but could be run on any subarea of the difference grid. This was done to isolate areas, such as areas of high depth difference (if any), to better evaluate and investigate potential accuracy problems. Junction analysis results are presented in Separates II of the DR for each sheet.

### D.1.5.2 Junctions

Junction analysis was conducted between seven out of the eight junctioning survey sheets assigned in the Project Instructions (H10835, H10894, H11832, H10850, H10836, H10915, and H10851), and also between sheets for this project where the data have been fully processed. Note that comparisons were not made against assigned junctioning sheet H13090 as it bordered H13221, which was not assigned as the LNM requirement for OPR-K371-KR-19 was met. For junction analysis, the current data were binned at a one-meter grid resolution using the CUBE algorithm. For assigned junctioning sheets, the comparison was made with the final deliverable BAG for that sheet, which was provided by NOAA under OPR-K371-KR-19. Details regarding the resolution of the sheet to sheet junctions are listed within each sheet's DR Separates II Crossline Comparison.

### D.1.5.3 Platform to Platform

Multiple platforms did not acquire data for OPR-K371-KR-19.

### D.1.6 Other Validation Procedures

Multibeam Ping and Beam Flags

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

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

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

Leidos and CARIS have collaborated to provide the ability to import multibeam GSF files into CARIS. Within the DAPR Appendices are tables, which represent commonly used definitions for these GSF beam flags, as well as their mapping to CARIS depth flag codes. A second table represents commonly used definitions for these GSF ping flags, as well as their mapping to CARIS profile flag codes.

Note that there is not a one-for-one match between CARIS Profile and Depth flags and GSF Ping and Beam flags. Therefore, upon the import of multibeam GSF files into CARIS, GSF defined flags such as: delayed heave applied, the applied tide type in use, and Class 1 not being met are not available in CARIS. As detailed in the tables of the DAPR Appendices, no flag is applied in CARIS to the HDCS (Hydrographic Data Cleaning System) files, upon import from GSF, for these GSF ping and beam flags.

## D.2 Imagery data Integrity and Quality Management

### D.2.1 Coverage Assessment

As stated in the HSSD, 100% side scan coverage is not sufficient for disproval of assigned or charted features. Therefore, an additional 100% side scan coverage was obtained over the specified search radius for assigned objects not identified in the initial 100% side scan coverage. The disproval coverage was verified by generating two separate coverage mosaics. The first 100% side scan coverage consisted of all initial survey lines, while the disproval side scan coverage consisted of any additional coverage over assigned objects that were found to not be present during survey operations. To accomplish this, a time window file listing the times of all valid online side scan data was created along with separate side scan file lists for the 100% coverage, and disproval coverage mosaics. Using SABER, the time window file and the side scan file lists were then used to create one-meter cell size mosaics in accordance with Section 8.2.1 of the HSSD. The two coverage mosaics were reviewed independently using tools in SABER, such as Gapchecker, to verify data quality and swath coverage. During data acquisition, preliminary coverage mosaics were also used to plan additional survey lines to fill in any data gaps. All final delivered coverage mosaics are determined to be complete and sufficient to meet the Project Instructions for side scan sonar coverage, unless otherwise noted in a sheet's DR.

Each side scan coverage mosaic is delivered as individual georeferenced raster files, per HSSD Sections 8.2.1 and 8.3.3.

### D.2.2 Contact Selection Methodology

After each survey day, a hydrographer reviewed the side scan sonar data for quality, bottom tracking, and contacts using SABER's Imagery Review and Contact Review programs. Within Imagery Review, the contact detections were overlain on the side scan sonar record. The side scan data within Imagery Review was down sampled using the Average Display Method. This was chosen since it provided the best general-purpose review settings. Down sampling is necessary because the number of pixels displayed is constrained by the width of the display window and the screen resolution. During review, the hydrographer assessed the overall quality of the data and defined any holidays in the data where the quality was insufficient to clearly detect seafloor contacts across the full range scale. The times and descriptions for any defined data holidays were entered into a "Side Scan Review Log" which was created and maintained for each sheet. The times of all noted side scan data gaps were also incorporated into the side scan data time window files that were then used to depict the data gap within the applicable side scan coverage mosaic as discussed in Section D.2.1. 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
- Towfish altitude requirements

The "Side Scan Review Log" for each sheet was maintained throughout final data processing. It incorporated all of the relevant information about each side scan data file, including the line begin and line end times, survey line name, corresponding multibeam file name(s), line azimuth, and any operator notes made during data acquisition. System-status annotations were recorded in the logs at the beginning of survey operations in each sheet, upon returning to the survey area, and at the JD rollover of each continuous survey day. These system-status annotations included; the mode of tuning (auto tuning was used throughout all survey operations), the tow point, the side scan range scale setting, the watchstander's initials, the side scan model in use, whether or not a depressor was in use on the side scan, weather conditions and sea state. These and any other necessary annotations were continuously updated throughout survey operations as needed in accordance with Section 8.2.3 of HSSD. Each sheet's "Side Scan Review Log" is included in Separates I of the sheet's DR.

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

The SABER Contact Review program opens the contact and all surrounding displayed side scan data at full resolution. The hydrographer can choose to zoom in or out to review the contact. When measuring contacts within Contact Review, the length is always the along track dimension and the width is always the across track dimension. Therefore it is possible to have a width measurement that is longer than the length measurement.

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

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

SABER generated side scan contact images for each contact within the XML and they are delivered for each sheet under the “HXXXXX/Processed/Multimedia” folder on the delivery drive, and referenced in the Side Scan Sonar Contacts S-57 file NOAA Extended Attribute “images” field. Also, for a subset of side scan contacts that have been correlated to a multibeam feature (maximum of two side scan contact images for each feature); the images are visible in the Feature Correlator Sheets referenced in the S-57 Feature File NOAA Extended Attribute “images” field.

Leidos also generated an S-57 file for each sheet to display the SSS contacts. The Side Scan Sonar Contacts S-57 file (.000) was generated through the same process used to build each sheet’s final S-57 Feature File, described in Section C.7, except with side scan contact information incorporated instead of multibeam feature information.

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

The NOAA Extended Attribute “images” field of each cartographic symbol details an associated JPEG image for the side scan contact it represents.

# E. Approval Sheet

This Data Acquisition and Processing Report (DAPR), Leidos Document Number 19-TR-039, applies to hydrographic project OPR-K371-KR-19. Survey data were collected from April 2019 through September 2019. The Project Instructions (PI) for OPR-K371-KR-19, reference the April 2018 version of the Hydrographic Surveys Specifications and Deliverables (HSSD); per guidance received from NOAA on 25 March 2019 and the waiver memorandum received on 05 November 2019 (provided in the Supplemental Correspondence with each sheet's Descriptive Report), Leidos is adhering to the March 2019 version of the HSSD. Additional project specific clarifications and guidance are located in Project Correspondence and Appendix II of the Descriptive Report (DR) for each sheet.

As Chief of Party, field operations and data processing for these hydrographic surveys were conducted under my direct supervision, with frequent personal checks of progress and adequacy. This Report and accompanying deliverable data items have been closely reviewed and are considered complete and adequate as per the Hydrographic Surveys Specifications and Deliverables, Project Instructions, and Statement of Work.

The survey data meets or exceeds requirements as set forth in the Hydrographic Surveys Specifications and Deliverables, Project Instructions, and Statement of Work. These data are adequate to supersede charted data in their common areas. This Report and all accompanying records and data are approved. All records are forwarded for final review and processing to the Processing Branch.

| Approver Name | Approver Title | Date | Signature |
|---|---|---|---|
| Paul L. Donaldson | Chief Hydrographer | 12/06/2019 | Paul L Donaldson<br>Digitally signed by: Paul L Donaldson<br>DN: CN = Paul L Donaldson C = US O = Leidos OU = A01427E0000015C7EA9ADE2000073EC<br>Date: 2019.12.06 17:18:34 -05'00' |
| Alex T. Bernier | Lead Hydrographer | 12/06/2019 | Alex T Bernier<br>Digitally signed by: Alex T Bernier<br>DN: CN = Alex T Bernier C = US O = Leidos OU = 7F0000010000015C894F07C100008A1A<br>Date: 2019.12.06 17:32:46 -05'00' |
| Bridget W. Bernier | Data Processing Manager | 12/06/2019 | Bridget W Bernier<br>Digitally signed by Bridget W Bernier<br>Date: 2019.12.06 17:11:47 -05'00' |
| Erin Markham | Lead Hydrographer | 12/06/2019 | Digitally signed by: Erin E Markham<br>Date: 2019.12.06 17:20:38 -05'00'<br>Erin E Markham |

# List of Appendices:

| ***Mandatory Report*** | ***File*** |
|---|---|
| *Vessel Wiring Diagram* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *Sound Speed Sensor Calibration* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *Vessel Offset* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *Position and Attitude Sensor Calibration* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *Echosounder Confidence Check* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *Echosounder Acceptance Trial Results* | OPR-K371-KR-19_DAPR_Appendices.pdf |

| ***Additional Report*** | ***File*** |
|---|---|
| *Data Processing Flow Diagrams* | OPR-K371-KR-19_DAPR_Appendices.pdf |
| *GSF Flag Mapping to CARIS Flag Codes* | OPR-K371-KR-19_DAPR_Appendices.pdf |