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National Oceanic and Atmospheric Administration
National Ocean Service

Data Acquisition & Processing Report

Type of Survey:	Basic Hydrographic Survey
Project Number:	OPR-E347-KR-22
Time Frame:	September - May 2023

LOCALITY

State(s):	Maryland
General Locality:	Central Chesapeake Bay

2022

CHIEF OF PARTY
Paul L. Donaldson

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Data Acquisition and Processing Report

Leidos
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A. System Equipment and Software

A.1 Survey Vessels

A.1.1 R/V Sea Innovator I

Vessel Name	R/V Sea Innovator I
Hull Number	R/V Sea Innovator I
Description	Leidos employed the survey vessel R/V Sea Innovator I, a 135-foot aluminum hulled vessel outfitted with the following major data acquisition systems, for the survey effort: 1. POS/MV 320 version V5 and IMU type 36 2. Teledyne RESON SeaBat T50 multibeam echo sounder (MBES) 3. Klein 4000 dual frequency side scan sonar (SSS) 4. AML Oceanographic (AML) Moving Vessel Profiler 30 (MVP30) sound speed profile (SSP) acquisition system The R/V Sea Innovator I (Figure 1) was equipped with shipboard systems including an autopilot, non-survey echo sounder, Differential Global Positioning System (DGPS), radars, Automatic Identification System (AIS), two 44 kilowatt (kW) diesel generators and a 58.5 kW payload generator. Accommodations for up to 6 surveyors were available within two cabins. For survey operations, the SSS winch and two 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. The POS/MV IMU was mounted approximately amidships, below the main deck, starboard of the vessel's keel. The MBES transducer and collocated AML MicroX surface sound speed sensor were hull-mounted approximately amidships, starboard of the vessel's keel. The SSS was towed from a stern mounted A-frame. 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 the Appendices.

Dimensions	*LOA*	135 ft
	Beam	26 ft
	Max Draft	9 ft
Most Recent Full Static Survey	*Date*	2022-02-27
	Performed By	Leidos

Figure 1: R/V Sea Innovator I

A.1.2 R/V Oyster Bay II

<table>
<tr><td>Vessel Name</td><td>R/V Oyster Bay II</td></tr>
<tr><td>Hull Number</td><td>R/V Oyster Bay II</td></tr>
<tr><td>Description</td><td>Leidos employed the survey vessel, the R/V Oyster Bay II, a 30-foot aluminum hulled vessel, which was outfitted with the following major data acquisition systems for the survey effort:
1. POS/MV 320 version V5 and IMU type 36
2. Teledyne RESON SeaBat T50 MBES
3. Klein 4900 dual frequency SSS
4. AML Oceanographic BaseX2 SSP acquisition systems

The R/V Oyster Bay II (Figure 2) was equipped with shipboard systems including an autopilot, non-survey echo sounder, DGPS, radar, and a 7 kW gas generator. The SSS was bow mounted. The MBES with collocated AML MicroX surface sound speed sensor were pole mounted on the port side off the aft main deck and gunwale. The POS/MV IMU was mounted on the MBES pole mount assembly, approximately on the vessel centerline. Configuration parameters, offsets, and installation diagrams for all equipment are included in the following sections of this Report and the Appendices.</td></tr>
<tr><td>Dimensions</td><td><table><tr><td>LOA</td><td>30 ft</td></tr><tr><td>Beam</td><td>9 ft</td></tr><tr><td>Max Draft</td><td>3 ft</td></tr></table></td></tr>
<tr><td>Most Recent Full Static Survey</td><td><table><tr><td>Date</td><td>2020-06-14</td></tr><tr><td>Performed By</td><td>Leidos</td></tr></table></td></tr>
</table>

Figure 2: R/V Oyster Bay II

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 RESON SeaBat T50

A RESON SeaBat T50 with an AML MicroX surface sound speed sensor was used for all MBES data collection onboard the R/V Sea Innovator I and the R/V Oyster Bay II. The RESON SeaBat T50 can be operated in Equi-Angle, Equi-Distant, or Intermediate Modes with a sliding scale of 10 to 1024 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 130 degree swath set by the coverage angle in the controller; and was in use as single frequency system primarily operating at 300 or 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 resulting settings and real-time data quality were continuously monitored by the watchstanders. If ever deemed necessary, a watchstander could disable the automatic tracker mode and manually adjust the system settings based on real-time quality monitoring. 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. To ensure least depths on items were captured, adaptive depth gates were disabled during item line data acquisition.

The RESON SeaBat T50 receiver and transducer were installed on the R/V Sea Innovator I's hull 2022-09-23 (JD 266). Alignments were determined via a Patch Test on 2022-09-28 (JD 271) and confirmed on 2022-09-29 (JD 272).

The RESON SeaBat T50 receiver and transducer were installed on the R/V Oyster Bay II on 2022-09-08 (JD 251). Alignments were determined via a Patch Test on 2022-09-09 (JD 252) and confirmed on 2022-09-11 (JD 254) post SBET applications. Additional alignment verifications were conducted throughout the survey effort. Please refer to the DAPR Appendices for further information on the Patch Tests performed.

Details of the arrays in use are captured in the Table below.

<table>
<tr><td>Manufacturer</td><td colspan="5">RESON</td></tr>
<tr><td>Model</td><td colspan="5">SeaBat T50</td></tr>
<tr><td rowspan="12">Inventory</td><td rowspan="6">R/V Sea Innovator I</td><td>Component</td><td>Sonar Processor</td><td>Projector</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>T50-R</td><td>TC2181</td><td>EM7218</td></tr>
<tr><td>Serial Number</td><td>08944920127</td><td>4620126</td><td>4620112</td></tr>
<tr><td>Frequency</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td>Calibration</td><td>2022-09-29</td><td>2022-09-29</td><td>2022-09-29</td></tr>
<tr><td>Accuracy Check</td><td>2022-09-29</td><td>2022-09-29</td><td>2022-09-29</td></tr>
<tr><td rowspan="6">R/V Oyster Bay II</td><td>Component</td><td>Sonar Processor</td><td>Projector</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>T50-R</td><td>TC2181</td><td>EM7218</td></tr>
<tr><td>Serial Number</td><td>3716025</td><td>2117070</td><td>3216025</td></tr>
<tr><td>Frequency</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td>Calibration</td><td>2022-09-11</td><td>2022-09-11</td><td>2022-09-11</td></tr>
<tr><td>Accuracy Check</td><td>2022-09-11</td><td>2022-09-11</td><td>2022-09-11</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. 4000

A Klein 4000 dual frequency side scan sonar (SSS) system was used for all SSS data collection onboard the R/V Sea Innovator I. The SSS data were collected at 100 kHz and 400 kHz concurrently. All SSS data delivered are 32-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-E347-KR-22, the SSS range scale was set by the watchstander at 50-meters based on the planned survey areas, the observed water depths and the observed environmental conditions.

Based on the SSS ping rates, maximum survey speeds were established to ensure coverage requirements were met in accordance with Section 6.1.2.2 of the HSSD. During survey operations, the Klein 4000 was towed from the R/V Sea Innovator I’s A-Frame while the SSS towfish altitude was controlled with the cable payout set by a watchstander via a Sea Mac winch’s remote controller. The cable payout was continuously monitored with a MacArtney sheave sensor and logged by ISS-2000.

Manufacturer	Klein Marine Systems Inc.			
Model	4000			
Inventory	*R/V Sea Innovator I*	*Component*	Klein Transceiver Processing Unit (TPU)	Towfish
		Model Number	14105729-03	4000
		Serial Number	051	016
		Frequency	N/A	100 kHz and 400 kHz concurrently
		Calibration	2022-09-29	2022-09-29
		Accuracy Check	2022-09-29	2022-09-29

A.2.3.2 Klein Marine Systems Inc. 4900

A Klein 4900 dual frequency SSS system was used for all SSS data collection onboard the R/V Oyster Bay II. The SSS data were collected at 455 kHz and 900 kHz concurrently. All SSS data delivered are 32-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-E347-KR-22, the SSS range scale was set by the watchstander at 50-meters based on the planned survey areas, the observed water depths and the observed environmental conditions.

Based on the SSS ping rates, maximum survey speeds were established to ensure coverage requirements were met in accordance with Section 6.1.2.2 of the HSSD. During survey operations, the Klein 4900 was pole mounted from the bow of the R/V Oyster Bay II.

<table>
<tr><td>Manufacturer</td><td>Klein Marine Systems Inc.</td></tr>
<tr><td>Model</td><td>4900</td></tr>
<tr><td>Inventory</td><td><table><tr><td>R/V Oyster Bay II</td><td><table>
<tr><td>Component</td><td>Klein Transceiver Processing Unit (TPU)</td><td>Towfish</td></tr>
<tr><td>Model Number</td><td>14105729-01</td><td>4900</td></tr>
<tr><td>Serial Number</td><td>072</td><td>070</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>455 kHz and 900 kHz concurrently</td></tr>
<tr><td>Calibration</td><td>2022-09-11</td><td>2022-09-11</td></tr>
<tr><td>Accuracy Check</td><td>2022-09-11</td><td>2022-09-11</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 both the R/V Sea Innovator I and the R/V Oyster Bay II, the port antenna was configured as the primary and the starboard antenna as secondary. Refer to the table below and Figure 3 for the POS/MV system details.

On the R/V Sea Innovator I, a GPS Azimuth Measurement System (GAMS) calibration was conducted on 2022-09-28 (JD 271) which confirmed the Baseline Vector values from the sensor dimensional offset survey of 2022-07-27 (JD 208). On the R/V Oyster Bay II, a GAMS calibration was conducted on 2022-09-09 (JD

252), which confirmed the Baseline Vector values from the sensor dimensional offset survey of 2020-06-14 (JD 166). Refer to the Appendices of this Report for the calibration and configuration reports.

Navigation data were post-processed to be in accordance with Section 3.5 of the HSSD. All post-processed navigation data used for application to final survey data were fully reviewed in SABER's Time-Series Viewer (TSView) program and were found to meet all accuracy and quality standards. Details on the PCS and Antenna 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.

Manufacturer	Applanix						
Model	POS/MV-320 Position and Orientation System Version 5						
Inventory	*R/V Sea Innovator I*	*Component*	IMU	PCS	Antenna	Antenna
		Model Number	IMU36	MV-320 Version 5	GA830	GA830
		Serial Number	3620	7958	11307	11302
		Calibration	N/A	N/A	N/A	N/A
	R/V Oyster Bay II	*Component*	IMU	PCS	Antenna	Antenna
		Model Number	IMU36	MV-320 Version 5	GA830	GA830
		Serial Number	3308	7585	7898	7903
		Calibration	N/A	N/A	N/A	N/A

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	11.21	11.21
ICD	11.21	11.21
Operating System	6.4.1	6.4.1
IMU Type	36	36
Primary GPS Type	BD982	BD982
Options	RTK-0, THV-0, NRE-0	RTK-0, THV-0, NRE-0

Figure 3: POS/MV Systems

A.5.2 DGPS

A.5.2.1 Applanix POS/MV-320 Position and Orientation System Version 5

For all survey platforms, the primary POS/MV navigation system was configured for the use of the WAAS. Refer to Section C.3.1.2 for further details on the use of DGPS over the course of survey operations.

Manufacturer	Applanix		
Model	POS/MV-320 Position and Orientation System Version 5		
Inventory	*R/V Sea Innovator I*	*Component*	DGPS Receiver
		Model Number	MV-320
		Serial Number	7958
		Calibration	N/A
	R/V Oyster Bay II	*Component*	DGPS Receiver
		Model Number	MV-320
		Serial Number	7585
		Calibration	N/A

A.5.2.2 Oceaneering C-Nav 3050

For all survey platforms the secondary C-Nav navigation system was configured for the use of the WAAS. Refer to Section C.3.1.2 for further details on the use of DGPS over the course of survey operations.

Manufacturer	Oceaneering		
Model	C-Nav 3050		
Inventory	*R/V Sea Innovator I*	*Component*	WAAS Receiver
		Model Number	3050
		Serial Number	23459
		Calibration	N/A
	R/V Oyster Bay II	*Component*	WAS
		Model Number	3050
		Serial Number	23464
		Calibration	N/A

A.5.3 GPS

A.5.3.1 Oceaneering C-Nav 3050

For all survey platforms 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 continuously calculated and plotted, with periodic checks for discrepancies by the watchstander. Raw observables from the C-Nav unit were recorded for use in the event that issues were observed during processing of primary positioning data. No C-Nav data were used for final navigation.

<table>
<tr><td>Manufacturer</td><td colspan="3">Oceaneering</td></tr>
<tr><td>Model</td><td colspan="3">C-Nav 3050</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Sea Innovator I</td><td>Component</td><td>C-NAV</td></tr>
<tr><td>Model Number</td><td>3050</td></tr>
<tr><td>Serial Number</td><td>23469</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
<tr><td rowspan="4">R/V Oyster Bay II</td><td>Component</td><td>C-NAV</td></tr>
<tr><td>Model Number</td><td>3050</td></tr>
<tr><td>Serial Number</td><td>23464</td></tr>
<tr><td>Calibration</td><td>N/A</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

On the R/V Sea Innovator I, an MVP30 and an AML MVP•X instrument were the primary sound speed equipment used to determine sound speed profiles (SSP) for corrections to MBES data. The MVP30 allows for efficient acquisition of underway sound speed profiles. During survey operations, the MVP•X unit was outfitted with sound velocity, pressure, and temperature Xchange sensors, then housed in a towbody and towed by the vessel to allow for regular MVP deployments. On the R/V Sea Innovator I, the MVP30 was mounted on the starboard stern quarter of the vessel. The deck unit consisted of an electrical winch, control box, remote control pendant and overboard sheave. The deck unit was interfaced to a control box inside the real-time acquisition van and to the MVP Controller software on a notebook computer which was monitored by a watchstander.

<table>
<tr><td>Manufacturer</td><td colspan="2">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="2">MVP30</td></tr>
<tr><td>Inventory</td><td>R/V Sea Innovator I</td><td><table>
<tr><td>Component</td><td>MVP System</td></tr>
<tr><td>Model Number</td><td>MVP30</td></tr>
<tr><td>Serial Number</td><td>M12037</td></tr>
<tr><td>Calibration</td><td>N/A</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 MVP•X instrument, compatible with the AML sound velocity, pressure, and temperature Xchange sensors noted above, was used in conjunction with the MVP30 for primary sound speed profile (SSP) acquisition on the R/V Sea Innovator I.

The individual sound velocity, pressure, and temperature Xchange sensors are directly connected to the head of the MVP•X instrument. The MVP•X instrument is then connected to the MVP30 control box system via the tow cable.

<table>
<tr><td>Manufacturer</td><td colspan="2">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="2">MVP•X</td></tr>
<tr><td>Inventory</td><td></td><td><table>
<tr><td>Component</td><td>Probe</td><td>Probe</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>MVP•X</td><td>MVP•X</td><td>MVP•X</td></tr>
<tr><td>Serial Number</td><td>008688</td><td>009032</td><td>009080</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table></td></tr>
</table>

A.6.3.2 AML Oceanographic Base•X2

AML Base•X2 instruments, compatible with AML sound velocity and pressure Xchange sensors, were the primary sound speed equipment used to determine sound speed profiles for corrections to MBES data on the R/V Oyster Bay II. Additionally, Base•X2 instruments were maintained onboard the R/V Sea Innovator I for the duration of the survey season to augment and compare 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.

<table>
<tr><td>Manufacturer</td><td colspan="5">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="5">Base•X2</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Sea Innovator I</td><td>Component</td><td colspan="3">Probe</td></tr>
<tr><td>Model Number</td><td colspan="3">Base•X2</td></tr>
<tr><td>Serial Number</td><td colspan="3">026114</td></tr>
<tr><td>Calibration</td><td colspan="3">N/A</td></tr>
<tr><td rowspan="4">R/V Oyster Bay II</td><td>Component</td><td>Probe</td><td>Probe</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>Base•X2</td><td>Base•X2</td><td>Base•X2</td></tr>
<tr><td>Serial Number</td><td>025410</td><td>026114</td><td>026255</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

A.6.3.3 AML Oceanographic MicroX

One AML MicroX SV probe, compatible with the AML SV Xchange sensors noted above, was collocated with each MBES system, mounted adjacent to the transducer head, to allow for real-time application of sound speed.

<table>
<tr><td>Manufacturer</td><td colspan="3">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="3">MicroX</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Sea Innovator I</td><td>Component</td><td>Sensor</td></tr>
<tr><td>Model Number</td><td>MicroX</td></tr>
<tr><td>Serial Number</td><td>11439</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
<tr><td rowspan="4">R/V Oyster Bay II</td><td>Component</td><td>Sensor</td></tr>
<tr><td>Model Number</td><td>MicroX</td></tr>
<tr><td>Serial Number</td><td>12014</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
</table>

A.6.3.4 AML Oceanographic SV Xchange

An AML 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 calibration details of all SV Xchange, P Xchange, and T Xchange sensors used during OPR-E347-KR-22.

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	SV Sensor
Model Number	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange	SV Xchange
Serial Number	206410	206148	204453	206514	206249	206515	206513	206512	207191	212094	209661
Calibration	2021-1[illegible]	2023-[illegible]	2020-[illegible]	2020-[illegible]	2022-1[illegible]	2023-[illegible]	2020-1[illegible]	2023-[illegible]	2022-1[illegible]	2023-[illegible]	20[illegible]-12-13

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 calibration details of all SV Xchange, P Xchange, and T Xchange sensors used during OPR-E347-KR-22.

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	305598	304601	305557	305558	305555	305840	307039
Calibration	2023-05-10	2023-05-10	2023-05-10	2022-11-22	2023-05-10	2022-11-22	2023-05-10

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 calibration details of all SV Xchange, P Xchange, and T Xchange sensors used during OPR-E347-KR-22.

<table>
<tr><td>Manufacturer</td><td>AML Oceanographic</td></tr>
<tr><td>Model</td><td>T Xchange</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td></td><td>
<table>
<tr><td>Component</td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td><td>Temperature Sensor</td></tr>
<tr><td>Model Number</td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td><td>T Xchange</td></tr>
<tr><td>Serial Number</td><td>404397</td><td>40370</td><td>404395</td><td>404438</td><td>404575</td></tr>
<tr><td>Calibration</td><td>2023-05-09</td><td>2023-05-08</td><td>2023-05-08</td><td>2022-11-28</td><td>2022-11-28</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

A.6.4 TSG Sensors

No TSG sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No other surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Leidos	ISS-2000 with Survey Planning	5.7.0.3.1	Acquisition
Leidos	SABER with Survey Planning	5.4.1.6.1	Processing
Leidos	iNavLog	2.7	Acquisition
Klein	SonarPro	14.1v99	Acquisition
AML Oceanographic	MVP30 Controller	2.4.8	Acquisition
AML Oceanographic	Seacast	4.4.0	Acquisition
Spectra Precision	Survey Pro Max	6.6.4.9	Acquisition
Applanix	POS/MV POSView	11.21	Acqusition
Applanix	POSPac MMS	8.8	Processing
Trimble	Business Center	5.30	Processing
SOLIDWORKS	Premium Center	SP3.0	Processing
Teledyne CARIS	HIPS and SIPS	10.4.3	Processing
ESRI	ArcGIS	10.6.1	Processing
NOAA	Extended Attribute Files	2022	Processing
NOAA	Pydro Explorer	22.1(r10531)	Processing
AutoCAD	Civil 3d	2022	Processing
AutoCAD	Map 3D	2022	Processing
Altova	XMLSpy	2023sp1	Processing
QPS	FMGT	7.10.3	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 4) 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 camera was 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.

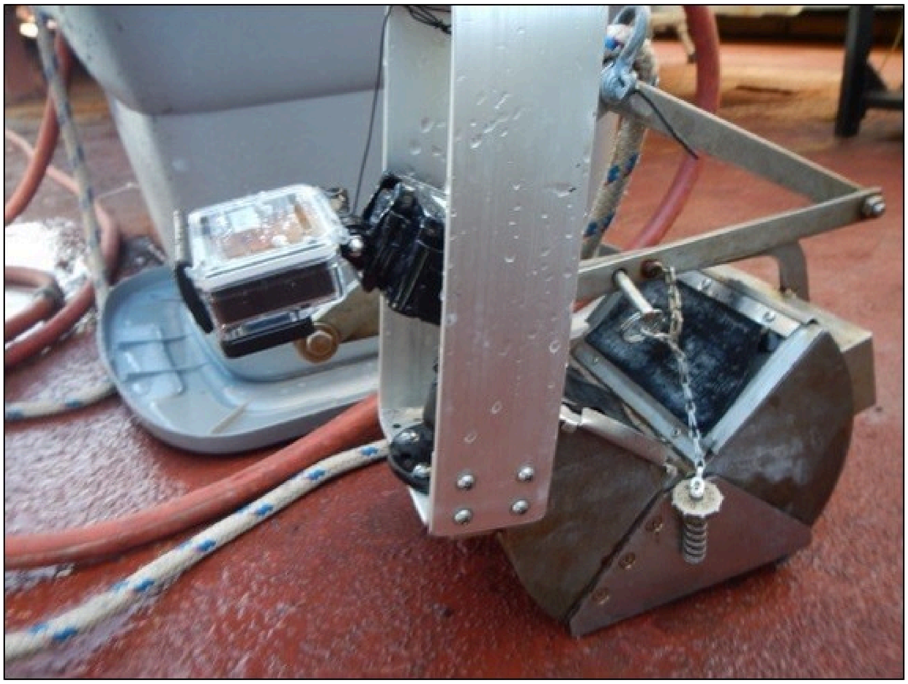

Figure 4: Bottom Sampler with Camera Attachment

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Static dimensional surveys were individually conducted on the R/V Sea Innovator I (July 2022) and R/V Oyster Bay II (June 2020), whereby each vessel reference frame was determined, as well as installation locations for all hydrographic survey sensors. On each vessel, 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.

On the R/V Sea Innovator I, the MBES was hull-mounted approximately amidships, just starboard of the keel. On the R/V Oyster Bay II, the MBES was pole mounted on the port side off the aft main deck and gunwale. For each vessel and individual static dimensional survey offset measurements were made from the POS/MV IMU reference point to the acoustic center of the MBES system's transducer array, as well as all other sensor and antenna locations used for hydrographic survey. Both the navigation and heave solutions were translated to the acoustic center location of the MBES system via configuration of the POS/MV controller software.

Figure 5 shows the R/V Sea Innovator I sensor configuration and the vessel offsets for the RESON SeaBat T50. The R/V Sea Innovator I vessel offsets are tabulated in Figure 6 which documents sensor offsets that were entered into the POS/MV software and ISS-2000. Figure 7 shows the R/V Oyster Bay II sensor configuration and the vessel offsets for the RESON SeaBat T50. The R/V Oyster Bay II vessel offsets are tabulated in Figure 8 which documents sensor offsets that were entered into the POS/MV software and ISS-2000. The offsets in POS/MV software are referenced to the IMU and in ISS-2000 are referenced to the sonar acoustic center. All measurements are in meters. Both 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 each vessel offset survey and results are provided in the DAPR Appendices.

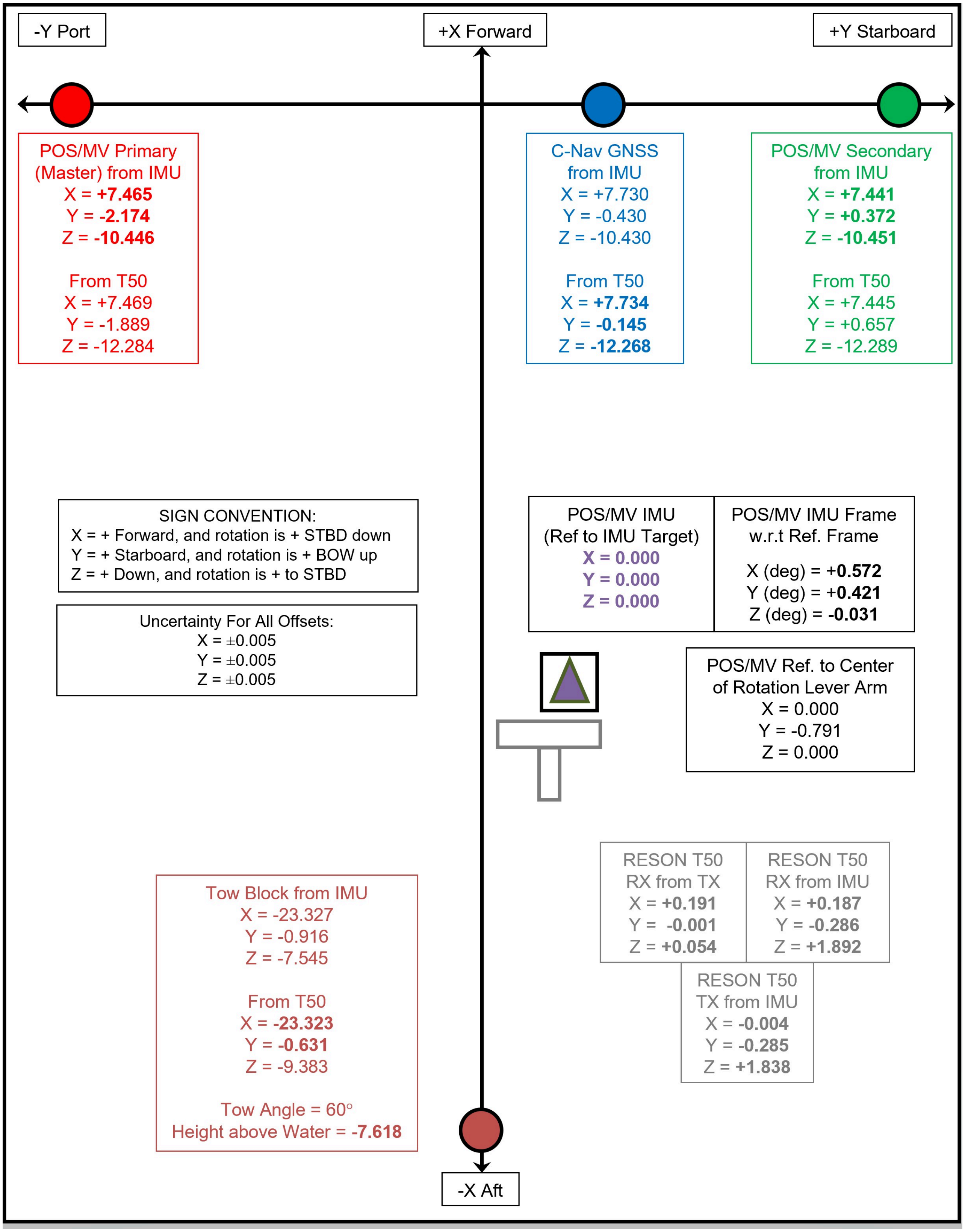

Figure 5: Configuration and Offsets of R/V Sea Innovator I Sensors (Measurements in Meters with 1-Sigma Uncertainty), RESON SeaBat T50

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	+0.572 degrees
			Y	+0.421 degrees
			Z	-0.031 degrees
Ref. to Primary GNSS Lever Arm (IMU to Master GA830 Antenna L1)			X	+7.465m
			Y	-2.174m
			Z	-10.446m
Ref. to Vessel Level Arm (IMU to RESON T50 Transducer)			X	-0.004m
			Y	-0.285m
			Z	+1.838m
Ref. to Center of Rotation Lever Arm (IMU to vessel CG)			X	0.000m
			Y	-0.791m
			Z	0.000m
Ref. to Sensor 1 Lever (IMU to RESON T50 Transducer)			X	-0.004m
			Y	-0.285m
			Z	+1.838m
GAMS Parameter Setup			X	-0.024m
			Y	2.546m
			Z	-0.005m
RESON T50 RX from TX	X	+0.191m		
	Y	-0.001m		
	Z	+0.054m		
Navcom C-Nav 3050 GPS Antenna from RESON T50 Transducer	X	+7.734m		
	Y	-0.145m		
	Z	-12.268m		
A-Frame Tow Block (X and Y from RESON T50 Transducer. Z is height above water).	X	-23.323m		
	Y	-0.631m		
	Z	-7.618m		

Figure 6: R/V Sea Innovator I Offsets, RESON SeaBat T50 (Measurements in Meters with 1-Sigma Uncertainty)

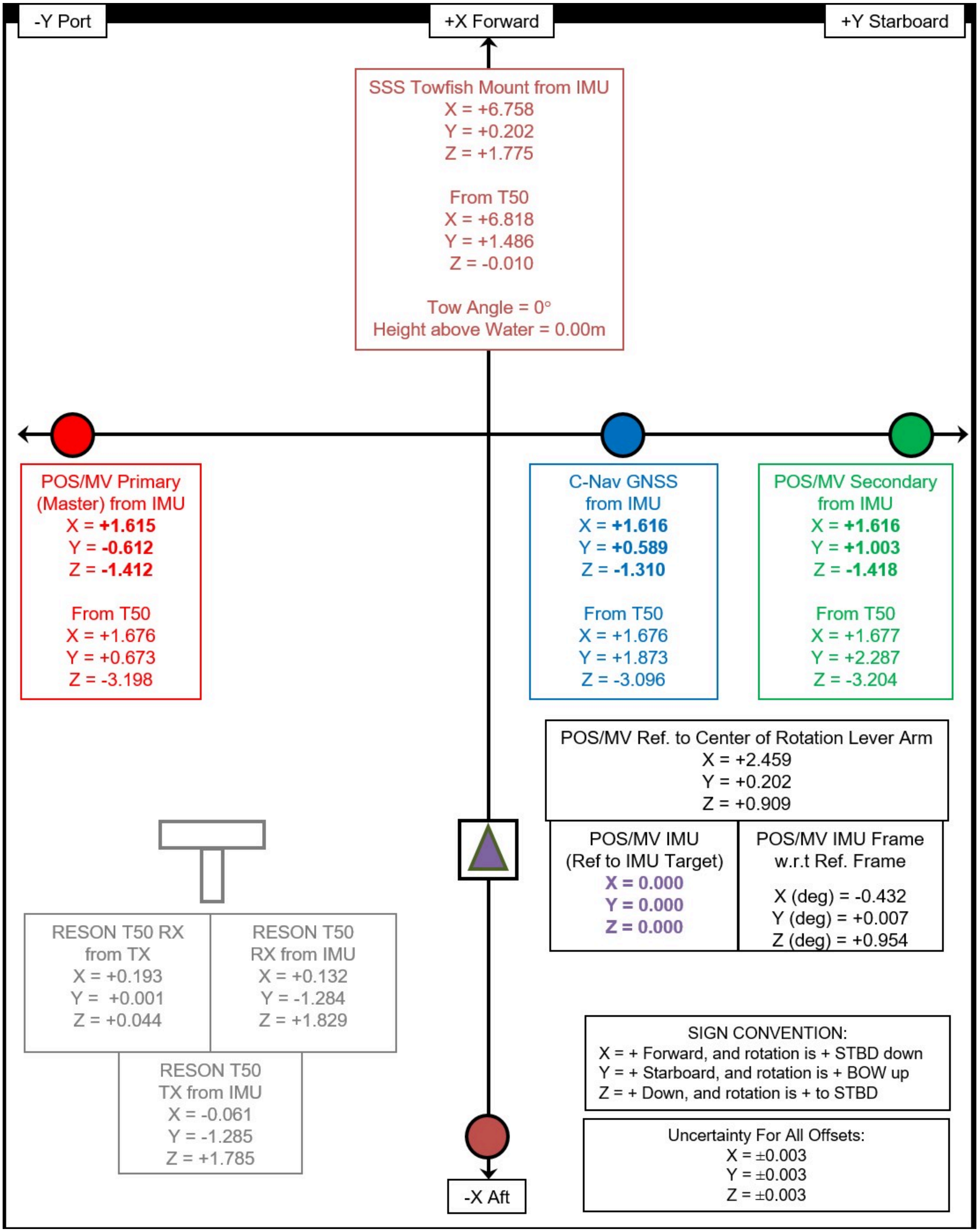

Figure 7: Configuration and Offsets of R/V Oyster Bay II Sensors (Measurements in Meters with 1-Sigma Uncertainty), RESON SeaBat T50

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	-0.432 degrees
			Y	+0.007 degrees
			Z	+0.954 degrees
Ref. to Primary GNSS Lever Arm (IMU to Master GA830 Antenna L1)			X	+1.615m
			Y	-0.612m
			Z	-1.412m
Ref. to Vessel Level Arm (IMU to RESON T50 Transducer)			X	-0.061m
			Y	-1.285m
			Z	+1.785m
Ref. to Center of Rotation Lever Arm (IMU to vessel CG)			X	+2.459m
			Y	+0.202m
			Z	+0.909m
Ref. to Sensor 1 Lever (IMU to RESON T50Transducer)			X	-0.061m
			Y	-1.285m
			Z	+1.785m
RESON T50 RX from TX	X	+0.193m		
	Y	+0.001m		
	Z	+0.044m		
Navcom C-Nav 3050 GPS Antenna from RESON T50 Transducer	X	+1.676m		
	Y	+1.873m		
	Z	-3.096m		
SSS Towfish Mount (X and Y from RESON T50 Transducer. Z is height above water).	X	+6.818m		
	Y	+1.486m		
	Z	0.000m		

Figure 8: R/V Oyster Bay II Offsets, RESON SeaBat T50
(Measurements in Meters with 1-Sigma Uncertainty)

B.1.1.1 Vessel Offset Correctors

Vessel	R/V Sea Innovator I			
Echosounder	RESON SeaBat T50			
Date	2022-07-27			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	-0.004 meters	0.005 meters
		y	-0.285 meters	0.005 meters
		z	1.838 meters	0.005 meters
	Nav to Transducer	*x*	-0.004 meters	0.005 meters
		y	-0.285 meters	0.005 meters
		z	1.838 meters	0.005 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	R/V Oyster Bay II			
Echosounder	RESON SeaBat T50			
Date	2020-06-14			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	-0.061 meters	0.003 meters
		y	-1.285 meters	0.003 meters
		z	1.785 meters	0.003 meters
	Nav to Transducer	*x*	-0.061 meters	N/A
		y	-1.285 meters	N/A
		z	1.785 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	

B.1.2 Layback

The R/V Sea Innovator I side scan towfish positioning was provided by ISS-2000 through a Catenary program that used vessel offsets, cable payout, and towfish depth to compute towfish positions. The tow point (or block) position was continually computed based on the vessel attitude, and the known offsets from the acoustic center of the multibeam system to the tow point (see Appendices of this Report). 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 known tow angle, 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 where it was merged with the

SSS data file in real-time during data acquisition. A remote winch controller inside the data acquisition ISO 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.

On the R/V Oyster Bay II, the side scan towfish positioning was also provided by ISS-2000 through the Catenary program described above to compute towfish positions. For this vessel, the tow point (bow mount) position was continually computed based on the vessel attitude, 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 (bow mount) position using a manually set cable out value of 0.0 meters in ISS-2000, the known tow angle of the bow mount, and the CMG of the vessel. The calculated towfish position was sent to the SSS system via the TowfishNav module of ISS-2000, at least once per second where it was merged with the SSS data file in real-time during data acquisition.

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

B.1.2.1 Layback Correctors

<table>
<tr><td>Vessel</td><td colspan="3">R/V Sea Innovator I</td></tr>
<tr><td>Echosounder</td><td colspan="3">Klein 4000</td></tr>
<tr><td>Frequency</td><td colspan="3">100.0 kHz</td></tr>
<tr><td>Date</td><td colspan="3">2022-07-27</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-23.323 meters</td></tr>
<tr><td>y</td><td>-0.631 meters</td></tr>
<tr><td>z</td><td>-7.618 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.005 meters</td></tr>
<tr><td>Frequency</td><td colspan="3">400.0 kHz</td></tr>
<tr><td>Date</td><td colspan="3">2022-07-27</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-23.323 meters</td></tr>
<tr><td>y</td><td>-0.631 meters</td></tr>
<tr><td>z</td><td>-7.618 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.005 meters</td></tr>
</table>

Vessel	R/V Oyster Bay II		
Echosounder	Klein 4900		
Frequency	455.0 kHz		
Date	2020-06-14		
Layback	*Towpoint*	*x*	6.818 meters
		y	1.486 meters
		z	0.000 meters
	Layback Error	0.003 meters	
Frequency	900.0 kHz		
Date	2020-06-14		
Layback	*Towpoint*	*x*	6.818 meters
		y	1.486 meters
		z	0.000 meters
	Layback Error	0.003 meters	

B.2 Static and Dynamic Draft

B.2.1 Static Draft

The RESON SeaBat T50 transducer was hull-mounted on the R/V Sea Innovator I approximately 4.272 meters below surveyed draft measurement points on the port and starboard rails of the vessel's main deck (Figure 9). To determine the draft, a metal draft bar was bolted into the draft measurement points on each rail and oriented to extend outboard far enough to allow a direct measurement with draft cord to the water line. Specifically, the distance from the bottom of the metal bar to the water surface was measured and then subtracted from the transducer hull depth to determine the draft of the transducer's acoustic center. For the R/V Sea Innovator I, static draft measurements were taken at the port and starboard sides of the vessel at every port call; prior to departure and after arrival, in order to prorate a daily draft accounting for fuel and water consumption.

The RESON SeaBat T50 was pole mounted on the R/V Oyster Bay II, from the port side off the aft main deck 1.587 meters below a surveyed draft measurement point on the gunwale MBES pole mount assembly (Figure 10). To determine the draft, the distance from the reference point to the water surface was measured and then subtracted from the transducer depth to determine the draft of the transducer's acoustic center. On the R/V Oyster Bay II the static draft measurements were taken daily before departure from the dock.

The measurements and resulting draft value were recorded in the Watchstander Log and a vessel Draft Log. New static draft values were entered into the ISS-2000 system.
The table below details the first static draft value measurements made from each vessel for OPR-E347-KR-22.

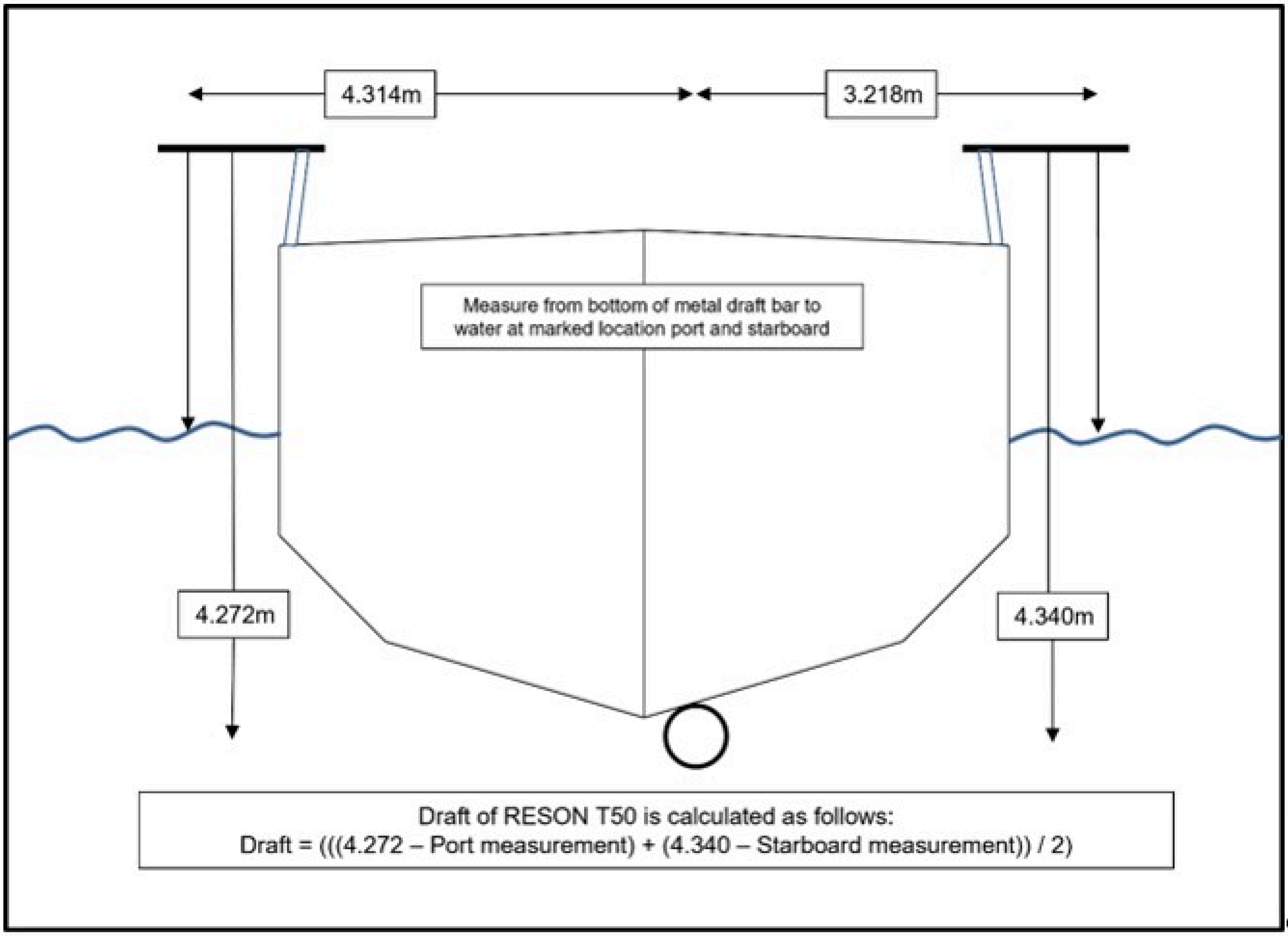

Figure 9: R/V Sea Innovator I RESON SeaBat T50 Draft Determination

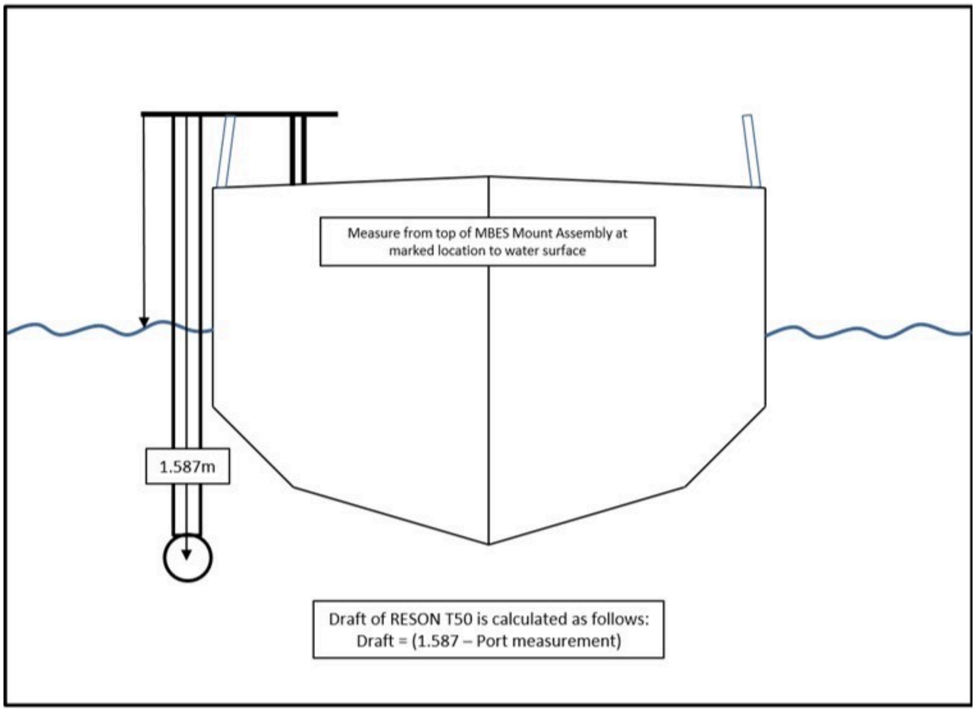

Figure 10: R/V Oyster Bay II RESON SeaBat T50 Draft Determination

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
R/V Sea Innovator I	2022-10-04	0.020 meters	1.780 meters	0.010 meters
R/V Oyster Bay II	2022-09-08	0.020 meters	0.970 meters	0.010 meters

B.2.2 Dynamic Draft

The R/V Sea Innovator I was fitted with RPM sensors which provided port and starboard main engine shaft RPM data to ISS-2000. The RPM sensor data were then continuously logged and used in conjunction with a settlement and squat look-up table in the ISS-2000 vessel configuration file to set the vessel dynamic draft. This combination allowed for constantly updated dynamic draft values to the MBES data during acquisition.

On the R/V Oyster Bay II, an engine RPM counter with digital display provided RPM values to the vessel captain and hydrographers. The RPM value was the manually input into the ISS-2000 system, which in conjunction with the settlement and squat look-up table in ISS-2000 applied a continuously updated settlement and squat value as data were collected.

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.

The dynamic draft values used by ISS-2000 during survey operations is based on a look-up table within the vessel configuration file. Settlement and squat values are entered into the lookup table to the nearest centimeter determined during the SAT of each vessel. For the R/V Sea Innovator I settlement and squat values have been determined during the 2022 SAT. The R/V Oyster Bay-II dynamic draft values were initially determined and set as the baseline during its inaugural SAT utilizing the Reson T-50 MBES in 2020. New values were determined during each subsequent independent SAT for the vessel and entered into a spreadsheet to determine a running average of the historical settlement and squat values. The running average was re-tabulated including 2022 inputs and updated in the vessel configuration file.

For dynamic draft determination, all settlement and squat look-up table values were zeroed out in the ISS-2000 vessel configuration file during SAT data acquisition. This allowed for an independent determination of settlement and squat values each time the test was performed.

The order of operations for the settlement and squat determination during each individual SAT is as follows. Initial drift (0 RPM) reference data were obtained by stopping the vessel and acquiring MBES data as the vessel drifted with the prevailing winds and current. A survey transect was then established in ISS-2000 Survey Planning Manager oriented perpendicular to and crossing over the drift line data. This survey transect was then run at least twice at every shaft RPM setting listed in the DAPR Appendices (at least one time in each direction), resulting in several pairs or larger groups of transects separated by RPM setting.

Several 0.5-meter CUBE PFM grids were created from the MBES data; one for each RPM setting group as well as one for the drift reference surface. These PFM grids were made using only the near nadir (±10 degrees) beams. Several difference grids were then created by subtracting the CUBE depth layer of the non-zero RPM grids from the CUBE depth layer of the zero RPM reference drift line. 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 setting and the reference drift line. The delta for each pair of RPM lines was computed, as shown in the DAPR Appendices. These values were then entered into a running average spreadsheet by vessel. The running average spreadsheets consisted of historical settlement and squat data from previous years. The newly computed settlement 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 SAT settlement and squat determination values were deemed satisfactory. The values for the R/V Sea Innovator I and the R/V Oyster Bay II were entered into each vessel's ISS-2000 vessel configuration file used for all data acquisition of OPR-E347-KR-22. The settlement and squat results for each vessel are documented 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 C.6 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, 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 not m/s.

B.2.2.1 Dynamic Draft Correctors

Vessel	R/V Sea Innovator I		R/V Oyster Bay II	
Date	2022-09-29		2021-03-15	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*
	306.00	0.02	600.00	0.00
	360.00	0.03	1000.00	0.01
	409.00	0.03	1600.00	0.03
	460.00	0.03	1800.00	0.03
	512.00	0.04	2000.00	0.02
	561.00	0.05	2200.00	0.02
	618.00	0.07	2400.00	0.00
	660.00	0.09		
	715.00	0.11		
	766.00	0.13		
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.00	0.05	0.00	0.05

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Sea Acceptance Tests (SAT) for the R/V Sea Innovator I and R/V Oyster Bay II, which included a system alignment verification, were conducted prior to the start of data acquisition for OPR-E347-KR-22.

For additional details and results on the SAT operations conducted refer to the Appendices of this Report.

For both vessels, 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. This test demonstrated that all RESON SeaBat MBES ping times collected by ISS-2000, as logged to 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 GAMS calibration verification on 2022-09-28 (JD 271 for the R/V Sea Innovator I, and on 2022-09-09 (JD 252) for the R/V Oyster Bay II. Refer to the Appendices of this Report for further information on GAMS.

Leidos' Patch Test (Alignment) utility 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 correctors 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 collected at least 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 2022-09-29 (JD 272) for the RESON SeaBat T50 installed on the R/V Sea Innovator I. Roll, pitch, and heading biases were determined on 2022-09-11 (JD 254) for the RESON SeaBat T50 installed on the R/V Oyster Bay II. Additional roll pitch, and heading biases were determined on 2022-12-30 (JD 364), and 2023-01-28 (JD 028) for the RESON SeaBat T50 installed on the R/V Oyster Bay II. Refer to the Appendices for details on the alignment biases determined for each vessel.

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 and a complete Mini Survey.

The SABER ACCUTEST performs a detailed beam-to-beam analysis of the multibeam data. For this test, two orthogonal survey lines were established over a featureless bottom and both run at the same vessel speed multiple times in each direction. A 1-meter CUBE PFM grid of the ±10 degrees near-nadir beams was generated. Then, a comparison was made from every beam across the entire swath of every ping to the near nadir reference CUBE surface. The results are presented in the Appendices of this Report.

The Mini Survey procedure was developed to mirror the survey efforts required on a full scale survey project. The Mini Survey provides 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, a Mini Survey is performed over a charted feature and surrounding area. Following data acquisition, standard processing procedures are followed, also refer to the flow diagram within the Appendices of this Report, to evaluate the data against all applicable specifications and quality standards. 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 as part the SAT operations to provide Quality Assurance (QA) for the MBES system onboard each vessel as specified within Section 5.2.3.1 of the HSSD. Refer to the Appendices of this Report for information regarding where the lead line comparisons were conducted on each vessel. For QA additional lead line comparisons were periodically conducted throughout the project in addition to review of the mainscheme to crossline data. Lead line results from SAT are presented in the Appendices of this Report.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>R/V Sea Innovator I</td></tr>
<tr><td>Echosounder</td><td>RESON SeaBat T50</td></tr>
<tr><td>Date</td><td>2022-09-29</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><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>-1.300 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.962 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>-0.500 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>
</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>R/V Oyster Bay II</td></tr>
<tr><td>Echosounder</td><td>RESON SeaBat T50</td></tr>
<tr><td>Date</td><td>2022-09-11</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><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>3.080 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Roll</td><td>0.018 degrees</td><td>0.050 degrees</td></tr>
<tr><td>Yaw</td><td>0.020 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>
</td></tr>
</table>

Date	2022-12-30		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	2.400 degrees	0.050 degrees
	Roll	0.040 degrees	0.050 degrees
	Yaw	0.020 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds
Date	2023-01-28		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	2.600 degrees	0.050 degrees
	Roll	-0.090 degrees	0.050 degrees
	Yaw	0.020 degrees	0.050 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds

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 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 operating systems to control data acquisition, navigation, data time tagging, and data logging.

Leidos maintains the ability to narrow the MBES swath width for the RESON systems as necessary to maintain data quality and meet the required IHO specifications. Specifics of MBES 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 for designating the swath data as either Class 1 or Class 2 based on the beam angle and user set parameters.

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 manually set to 130 degrees (65 degrees per side). Swath data flagged as Class 1 or Class 2 were used for grid generation. 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.

The OPR-E347-KR-22 Project Instructions documented the coverage requirements for these sheets as Object Detection Coverage, Complete Coverage, or a combination of the two. Refer to each sheet’s Descriptive Report (DR) for the assigned coverage requirement. Leidos chose to achieve Object Detection Coverage by using a combination of Option A: Object Detection Multibeam Coverage and Option B: 200% Side Scan Sonar Coverage with Concurrent Multibeam (HSSD Section 5.2.2.2) and Complete Coverage using Option B: 100% Side Scan Sonar Coverage with Concurrent Multibeam (HSSD 5.2.2.3). The resultant achievable MBES bottom coverage was controlled by set survey line spacing, based on SSS range scale, and the various water depths within the survey areas, therefore, 100 percent MBES coverage was not achieved in all areas, nor was it required by the Project Instructions. Refer to each sheet’s DR for details on SSS range scale and survey line spacing.

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 R/V Sea Innovator I, these files were archived to the on-board NAS for initial processing and QC review at the completion of each survey line. On the R/V Oyster Bay II, these files were archived to an on-board SABER processing computer for initial processing via an automated routine in SABER 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), and time that 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. In all cases, mainscheme and crossline data were delivered in separate GSF files.

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.

Acquisition logs were generated on a daily basis via the Leidos iNavLog program. All major data acquisition operations are automatically tracked and captured by iNavLog via a network connection monitoring the message files within the ISSC dataset. Additionally, iNavLog accepts manual user entries 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 MBES line purpose. 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 designed for the watchstander to generate an acquisition log of all entries per Julian Day, which is then output to a Microsoft Excel spreadsheet. Acquisition logs are reviewed daily, and throughout data processing operations.

Data Processing Methods and Procedures

Post processing was performed on the survey vessel R/V Sea Innovator I, in an established Field Office, and in the Newport, RI Data Processing Center (DPC). MBES and SSS data were processed and reviewed on computers with the Linux operating system (Red Hat Enterprise 7) which ran Leidos' SABER (Survey Analysis and Area Based Editor) software. Survey planning, data processing, and data analysis were carried out using the Leidos SABER software for Linux operating systems. Onboard the R/V Sea Innovator I and in the Newport, RI DPC, data were stored on a Network Attached Storage (NAS) system that all computers were able to access. Additionally, the DPC, Field Office, and the R/V Sea Innovator I were outfitted with Windows 10 workstations to allow for certain aspects of processing as needed.

As discussed previously, once a MBES file was archived to the on-board storage locations data processing commenced.

The MBES data were reviewed in SABER's MultiView Editor (MVE) program to flag erroneous data such as noise or fish, and to designate features. 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 editor by flagging the least depth beam 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.

An additional initial processing step (besides reviewing and editing the data) was to apply delayed heave to the GSF files. The process to apply delayed heave used the Applanix TrueHeave™ files logged in ISS-2000 (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.

To meet Ellipsoid Referenced Survey specifications, Leidos generated post-processed smoothed best estimate of trajectory (SBET) files through Applanix POSPac MMS software. The SBET data were then applied to the GSF multibeam data through SABER's MergeNav program (refer to Section C.4). The application of SBET files to GSF corrects all GSF data to NAD83 datum.

Following the application of the post-processed 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 written 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

Final depth data are provided through BAG surfaces utilizing the Combined Uncertainty and Bathymetric Estimator (CUBE) algorithm to compute the depth surface.

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" using the Prior disambiguation method. Once the "best" hypothesis had been selected for each node, the hypotheses were used to populate a bathymetric surface. Settings used for establishing CUBE were in agreement with the HSSD.

SABER has incorporated CUBE processing into the PFM layer structure. When building a CUBE PFM layer, the following surfaces are written to the PFM grid.
-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. 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. Then Leidos converted the PFM grid to a Bathymetric Attributed Grid (BAG). This process was done through the use of the Convert PFM to BAG utility in SABER. 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 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 1.5.1.1, uncompressed, and include both the Elevation Solution Group surfaces and the Node Group surfaces.

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-E347-KR-22 Sheets 1 through 7, and Sheet 9 BAG files the Corrector surface was populated with VDatum values gridded through SABER (OPR-E347-KR-22_NAD83_VDatum_MLLW.cov). For OPR-E347-KR-22 Sheet 8 the NOAA provided VDatum coverage was gridded through SABER and attached as the Corrector surface. See Section C.3.2.1 for more details of VDatum application.

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 information specific to the sheet.

Each BAG is reviewed through SABER to ensure that each node of all surfaces within the BAG files match the source PFM.

C.1.4.2 Depth Derivation

Leidos utilizes all the surfaces available within the PFM structure to assess data quality and to identify features within the multibeam data. Using the CUBE surfaces as well as the bathymetry points, the multibeam data are reviewed 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 Hypothesis Final Uncertainty layer. Any edits performed were then unloaded back to the GSF files. The SABER Check PFM Uncertainty routine and the SABER Gapchecker routine were both run and results reviewed for any remaining outliers or coverage gaps. Leidos repeated this analysis until review was determined to be final.

C.1.4.3 Surface Computation Algorithm

For each survey sheet, all bathymetry data were processed into a PFM CUBE surface at the appropriate single resolution surface. 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. Avg TPU). 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. Avg 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 S-44 6th Edition Order 1a. These nodes were investigated individually and typically highlighted areas where additional data outlier cleaning was necessary. Nodes found in the final PFM CUBE grid that still exceeded uncertainty thresholds 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.

For final generation, PFM grid(s) were built at a resolution based on HSSD Section 5.2.2.2 or HSSD Section 5.2.2.3, for analysis using SABER and MVE. 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.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

In accordance with the HSSD, Leidos collected MBES backscatter in all GSF data acquired. 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. During data acquisition, the MBES settings were checked to ensure acceptable quality standards were met and to mitigate any acoustic saturation of the backscatter data. The MBES system settings once established, for power, gain, pulse length, absorption, and spreading were kept static during data acquisition. The first survey day from the R/V Oyster Bay II frequency was set to 400kHz, then for the remainder of the survey the R/V Oyster Bay II was set at 300kHz.

Data Processing Methods and Procedures

Throughout data acquisition, the MBES backscatter were routinely processed for QC purposes by using QPS FMGeocoder Toolbox (FMGT) software. FMGT was utilized to import and process the MBES backscatter. After the MBES data were fully processed and reviewed in SABER, the GSF data were imported into FMGT for MBES backscatter processing, all MBES data were utilized to generate mosaics. The data were grouped by vessel and then by acoustic frequency. The R/V Sea Innovator I conducted all data utilizing the 400kHz while the R/V Oyster Bay II acquired data at 400kHz and then 300kHz. As the vessels and frequencies were not calibrated, there may be more than one MBES backscatter mosaic provided for each sheet. Mosaics were reviewed to confirm the coverage requirements as outlined in the Project Instructions and specified within HSSD Section 6.

Upon import into FMGT, the absorption was adjusted based on an average from the SSP data. For the R/V Sea Innovator I the absorption was derived by calculating the salinity from the SSP data (which from the MVP stored sound velocity and temperature measurements) using the Chen & Millero (1997) equation to derive the speed of sound. Then the Francois and Garrison model (1982) was used to calculate absorption based on the speed of sound, frequency, and pH. This was analyzed for all SSP casts and upon review, an average value of 70.7dh was applied in FMGT to all MBES backscatter from the R/V Sea Innovator I. A similar analysis was conducted on all data for the R/V Oyster Bay II, as the Base X2 was the source for SSP files, the temperature and salinity were derived utilizing the Chesapeake Bay Operational Forecast System (CBOFS), comparing the date and time from the SSP file against the CBOFS data. Then the same model was used to calculate absorption. The R/V Oyster Bay II had a broader geographic and spatial area during the project, therefore a daily absorption average was utilized for the R/V Oyster Bay II data; refer to each Sheet DR for the daily average.

Per HSSD Section 6.2.3.5, the mosaic resolution was dependent on the acoustic frequency, for all data the minimum resolution utilized was 2-meters. Per HSSD Section 8.3.4 mosaics were exported from FMGT as a floating GeoTiff, value of -9999 for no data.

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). The SS-ACQ was integrated with the ISSC for NTP timing and towfish navigation.

Survey operations were conducted at set line spacing optimized for the sonar range scale in order to achieve 100% SSS coverage (for Complete Coverage) and 200% SSS coverage (for Object Detection and disprovals within Complete Coverage). Additional lines were acquired to obtain a second set of 100% SSS coverage for meeting 200% coverage in Object Detection survey specifications. During survey operations, 32-Bit (Klein 4000 and 4900) digital data from the TPU were acquired, displayed, logged, and QC'd on the Leidos SS-ACQ system running Klein's SonarPro software. 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 a user defined time interval, 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 storage locations for initial post processing in SABER's Imagery Review and associated programs. 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, JD that the data file was collected, calendar date, and time that the file was created.

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 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 200% mosaics for object detection coverage surveys, and 100% or disproval coverage mosaics for complete coverage surveys. Offline SSS data refers to the data logged within a SSS XTF file which were not used for generating either coverage mosaic.

In order to correlate individual SSS files to their associated survey lines, Leidos manually changed SSS file names in SonarPro 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 Log and Side Scan Review Log.

Refer to Section B.1.2 for information about the SSS towfish positioning.

For towed SSS operations, the SSS towfish depth off bottom (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 Project Instructions for OPR-E347-KR-22 stated that in 8 meters water depth and shoaler, side scan data may be acquired at an altitude of 6% to 20% of the range. In any instance where towfish altitude was lower than the requirements set forth in either the Project Instructions or Section 6.1.2.3 of the HSSD, the SABER side scan mosaic generation procedure clipped the SSS across track swath coverage to be within specifications. 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 towed SSS operations, 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.

Data Processing Methods and Procedures

Side scan sonar data processing was a multi-step process from updating the towfish navigation and heading in the XTF files through reviewing the imagery, identifying contacts and data coverage.

The SABER Navup and xtf_io routines were used in the first stages to update the SSS data with 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 and position for each ping record (as opposed to the 1 Hz position and heading data recorded during data acquisition).

All SSS data are delivered with completely corrected SSS positions.

SSS data quality and contact identification were conducted within SABER. Each XTF file was reviewed to assess bottom tracking (towfish altitude), quality of data, and contacts. Refer to Section D.2.2, for additional information regarding SSS analysis.

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

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 the primary POS/MV and secondary C-Nav systems were configured for the use of WAAS to improve 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

Data Acquisition Methods and Procedures

During data acquisition, predicted tides were applied to all MBES data through ISS-2000. The tidal zoning were downloaded from NOAA Center for Operational Oceanographic Products and Services (CO-OPS) and the water level files were downloaded from the CO-OPS Tides and Currents website.

At the end of each day, SABER's Check Tide Corrections in GSF utility was run to confirm that all the MBES 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 Ellipsoid Referenced Survey (ERS) water levels.

Data Processing Methods and Procedures

The VDatum separation model was the source of final water level corrections for OPR-E347-KR-22, as specified in the Project Instructions, which reduced the MBES sounding data to MLLW through ERS procedures.

As noted in Section C.1.4.1 for OPR-E347-KR-22 Sheets 1 through 7 and Sheet 9 were processed with VDatum through SABER. For OPR-E347-KR-22 Sheet 8 the NOAA provided VDatum coverage (OPR-E347-KR-22_CMMB_alt_NAD83-MLLW_xGeoid20B.csar) was gridded through SABER. Sheet 8 was processed differently than the other Sheets of OPR-E347-KR-22 as the VDatum model itself was found to not fully cover the eastern bounds of Sheet 8 within a narrow passage of water surveyed which was surrounded by land areas on three sides. Leidos confirmed that the NOAA provided VDatum coverage file (OPR-E347-KR-22_CMMB_alt_NAD83-MLLW_xGeoid20B.csar) fully covered the bounds of Sheet 8, and as such this file was used for water level corrections on Sheet 8.

After SABER's MergeNav (detailed in Section C.4) process was successful on the MBES data, the VDatum data were applied through SABER. The SABER 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 is not restricted to a single Area of VDatum to determine the derived solution. During the calculation of the separation value, SABER also calculates an uncertainty value as defined by the VDatum standard. SABER can operate with a user override uncertainty value or to use the calculated VDatum values. 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. Leidos used the VDatum information as provided in the Project Instructions with the exception of the single uncertainty value, refer to Project Correspondence for approval by NOAA to utilize the calculated values from VDatum and not from the provided surface and uncertainty listed in the final Project Instructions.

When updated water level correctors were applied to the GSF files, SABER 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.
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 nor is one provided by Leidos. The final VDatum separation data provided with each sheet's delivery represent the data generated in SABER by Leidos.

MHW VDATUM Model				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
4.1.2	2018	MDVAchb12_8301	8301	9.0 centimeters
MLLW VDATUM Model				
VDatum Version	Geoid	Area	Area Version	Separation Uncertainty
4.1.2	2018	MDVAchb12_8301	8301	9.2 centimeters

Figure 11: VDatum Information from Project Instructions

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, MBES data had predicted tides applied in real-time via ISS-2000. In order to correct the MBES 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 time of acquisition were not vertically referenced to the ellipsoid, however, all final data delivered are vertically referenced to the ellipsoid. This approach has been deemed acceptable by NOAA.

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 MBES data they reduced heave artifacts present from variables such as sea state and survey vessel maneuvering, which are commonly observed in MBES data with only real-time heave applied.

Data Processing Methods and Procedures

When delayed heave corrections were applied to the MBES 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 MBES data were reviewed using SABER’s Check Heave to verify that the delayed heave values were applied and flagged appropriately. The Check Heave program reads through the ping flags of each GSF record to check the application of delayed heave. When the Check Heave program found any instances of delayed heave not applied, it created output report files which included the corresponding GSF filename, as well as the time range for the gap in delayed heave application. The Check Heave reports were then used to further investigate all instances of gaps in delayed heave application.

Leidos endeavored to have delayed heave applied to all soundings of MBES 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 consistent with the surrounding available delayed heave values.

Leidos utilized Applanix POSPac MMS software with the Post-Processed Trimble CenterPoint® RTX™ (Trimble PP-RTX) option for all post processing of navigation trajectories. Refer to Section A.7 for the software version of POSPac MMS in use for processing. The final navigation solutions applied to the MBES data were derived from the raw navigation data of the POS/MV mentioned above in the Data Acquisition Methods of this section. All raw positioning files used to generate final trajectory solutions 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-E347-KR-22.

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 TSView to perform QC and review the trajectory files for spikes. Files were reprocessed in POSPac MMS with additional data or reconfiguration if ellipsoid height or vertical uncertainty spikes in the SBET were observed.

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 real-time data acquisition, and replaces it with the post-processed data from the SBET files. This process also stores the ellipsoid 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 uncertainty and other information about the source of the updated navigation file (SBET) being applied. The calculated uncertainties from the navigation system are written into the H/V Nav Error record, these values are then used during the overall uncertainty calculation and the modeled value stored within the SABER EPF are not used; refer to the DAPR Appendices. MergeNav utilized a linear interpolation between ellipsoidal heights.

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 onboard the R/V Sea Innovator I. Additionally, AML Base•X2 instruments, also compatible with Xchange sensors, were maintained onboard the R/V Sea Innovator I to augment the MVP30 data collection. The AML Base•X2 instruments were the primary means used to collect SSP data onboard the R/V Oyster Bay II. 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:
-Whenever 2 meters per second (m/s) difference was observed between the real-time surface sound speed (measured by a sound speed sensor located at the MBES transducer) and the recorded sound speed at the transducer depth in the currently applied SSP. -Real-time data of the towed MVPX sound speed sensor was also monitored for 2 m/s differences with the applied SSP.
-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.

During MBES acquisition, SSP casts were uploaded to ISS-2000 immediately after they were taken. In ISS-2000 Sound Velocity Profile Generator (SVPG) program, the profiles were reviewed for quality, edited as necessary, compared to the preceding casts, and then applied (loaded into the MBES system for use). Once applied, the MBES system used the SSP data for depth calculation and ray tracing corrections to the MBES data. The application of SSP data are automatically documented within the iNavLog database and are reported within the Watchstander Log for each sheet. If sounding depths exceeded the cast depth, ISS-2000 used the deepest sound speed value of the profile to extend the profile to the maximum depth. ISS-2000 is also configured to provide a warning to the watchstander when the profile does not reach at least 80% of the maximum depth. All MBES data through ISS-2000 are corrected for SSP based on real-time application.

Additional factors the hydrographer considered in determining how often a SSP cast was needed included the 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 MBES 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.

The Environmental Manager module in ISS-2000 displayed a real-time plot of three variables: the sound speed measured at the transducer depth of the currently applied SSP cast, the observed sound speed from the AML MicroX sensor 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. Watchstanders either acquired new SSP casts or re-applied a more appropriate previous SSP.

During the surveys it was not always possible to maintain a difference less than 2 meters per 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 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. If present, sound speed related issues will be discussed in each sheet's DR.

Confidence checks of the SSP data were periodically conducted by comparing two or more casts taken simultaneous or immediately consecutive using different sound speed sensors

For all the sensors used to acquire sound speed data for OPR-E347-KR-22, the serial numbers and calibration dates are provided in Section A. Copies of the calibration records are in the DAPR Appendices.

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 MBES 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 MBES data. The SSP file selected to apply in post-processing was always near in time to the MBES ping time, as the SABER TPU Model takes into account the age of the sound speed cast in relation to the MBES data. An older SSP file increases the associated uncertainty in the MBES data. Sound speed profiles applied to online MBES data, used to generate final coverage, 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.

Individual SSP files applied to the MBES contributing to final surfaces (Used for Final Surfaces) are provided as well as the SSP files utilized during the SABER's calculation of TPU (Used for Closing) are provided with each sheet under the HXXXXX/Processed/SVP/ directory. Additionally, Once the SSP data were determined to be final, the files were concatenated and formatted for use in CARIS these files are provided in a separate folder on the delivery drive: "HXXXXX/Processed/SVP/CARIS_SSP".

For the NCEI sound speed data submission, SSP casts were imported into the NOAA 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 two sub-folders, which correspond to the purpose of each cast. In accordance with HSSD Section 8.3.6 NCEI files will be delivered prior to the submission of the final sheet for OPR-E347-KR-22.

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 sonar UI to allow for real-time application of surface sound speed. The MicroX unit was also integrated with the ISS-2000 system through a parallel data stream 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. This comparison allowed the watchstander to observe when the delta between the two sound speed values exceeded the threshold of two meters per 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 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, then calculates cumulative system uncertainty (the TPU value). The data needed to drive the error model were captured as parameters taken from the SABER EPF, which is an ASCII text file 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. Examples of uncertainties stored in the GSF file versus the model EPF values are the navigation uncertainty and the separation 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. Additionally, when the SeaBat T50 is operating in FM mode there are uncertainty values stored within the GSF from the sonar which are used in place of values within the EPF file.

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 6th 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 6th 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.

The values entered into the SABER EPF for OPR-E347-KR-22 are documented within the DAPR Appendices. All parameter uncertainties in the EPF 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

C.6.2.1 A Priori Uncertainty

Vessel		R/V Sea Innovator I	R/V Oyster Bay II
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees
Navigation Sensor		0.02 meters	0.02 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
R/V Sea Innovator I	During real-time data acquisition an EPF within ISS-2000 was used for the application of TPU values to the MBES data. As such, the raw bathymetry data, written to GSF files, were fully corrected with uncertainties associated with each sounding at the time of acquisition.
R/V Oyster Bay II	During real-time data acquisition an EPF within ISS-2000 was used for the application of TPU values to the MBES data. As such, the raw bathymetry data, written to GSF files, were fully corrected with uncertainties associated with each sounding at the time of acquisition.

C.7 Shoreline and Feature Data

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

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

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

Included with each sheet’s delivery is an S-57 Feature File generated through SABER, 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. Following the IHO S-57 standard and the HSSD each sheet’s S-57 Feature File is delivered in the WGS84 datum and is unprojected with all units in meters. When applicable a feature was set within the MBES data and stored as a feature flag within the GSF structure (see DAPR Appendices). Per HSSD Section 2.2 the feature position within MBES and surfaces are in the NAD83 datum. SABER converts the position from the GSF (NAD83 datum) to WGS84 datum for compliance with HSSD and IHO to generate the S-57 file. Depending on geographic reference there may be approximately a 1-meter difference comparing positions between NAD83 and WGS84. Therefore, if the feature overrides from the BAG surface are compared to the Final Feature File S-57 positions it is anticipated that there would be positional differences exceeding those listed in Section 7.4 of the HSSD; however, SABER's implantation of CUBE and the GSF structure provide correlation that with a feature over-ride set the CUBE depth is within precision stated in HSSD Section 7.4.

Depth data presented in the BAG files for each sheet are delivered in NAD83 datum; per HSSD Section 2.2.

As specified in the HSSD, Leidos integrated the NOAA Extended Attributes into SABER's implementation of S-57. When appropriate the NOAA Extended Attributes have been classified for each feature within the S-57 Feature File.

Features were included in each sheet's S-57 Feature File as necessary based on classification of a feature identified within the sheet and information provided from the NOAA Composite Source File (CSF). For assigned features from the NOAA CSF, the investigation requirements were followed for determining if the data were to be included within the sheet's S-57 Feature File.

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.

Each sheet's S-57 Feature File was quality controlled with 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 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 and dive light on the Petite Ponar Grab system, which was used to obtain short videos of the seafloor at the sample site when possible. 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, using block and line, to the seafloor where the pinch-pin released and tension on the line during recovery actuated the scoops which captured sediment. 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; this information is stored within the Watchstander Logs.

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 IHO S-57, (see Section C.7 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 Branch is certified ISO 9001:2015 compliant, 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.

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 loss of sensor data, 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-E347-KR-22 project area, and previously downloaded NOAA predicted tide data from NOAA tide stations. Also, during real-time data acquisition, an EPF within ISS-2000 was used for the application of TPU values to the MBES data. As such, the raw bathymetry data, written to 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 in the field. 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 and flagging features.
-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 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.
-Identification of significant features for investigation with additional MBES coverage.
-Turning unacceptable data offline.
-Turning additional data online.
-QC review of MBES backscatter data
-Generation of MBES and SSS track line plots.
-Junction analysis (mainscheme depth data to crossline depth data)
-SSS contact identification with SABER's 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 and MBES coverage.

On a daily basis, the MBES data were binned into minimum depth layers, where each bin is populated 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 MBES data, as applicable.
-Generation of SBET data through Applanix POSPac MMS software.
-Application of SBET data to the MBES data through SABER's MergeNav.
-Application of VDatum separation model as water level correctors to MBES data.

-Re-computation of TPU for each depth value in the MBES data.
-Generation of a CUBE PFM surface for analysis of coverage, areas with high TPU, features, etc.
-Perform junction analysis comparing mainscheme depth data to crossline depth data, through surface difference review
-Perform junction analysis comparing the current sheet to adjacent sheets.
-Generation of final CUBE PFM surface.
-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 BAG files and metadata products.
-Generation of final MBES Backscatter mosaics.
-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 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, survey operations for OPR-E347-KR-22 were conducted with varied line spacing that was optimized to achieve either 100% or 200% side scan sonar coverage in order to fulfill the specified coverage requirements (Complete Coverage or Object Detection Coverage, respectively). The SABER Gapchecker utility was run on the CUBE surface to identify and flag any areas of data holidays exceeding the HSSD requirements. In addition, the entire surface was visually scanned for holidays. Leidos received guidance from NOAA (email 02/22/23) that MBES holidays are not considered holidays if the concurrent SSS data is of sufficient quality and coverage to ensure no features exist in those gaps. 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 specified in Sections 5.2.2.2 and 5.2.2.3 of the HSSD were met.

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, a CARIS vessel file will be all zeros, as stated in HSSD Section 8.3.2.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Leidos conducted crossline and mainscheme junction analysis utilizing a difference surface. 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. During data acquisition, comparisons of mainscheme (Class 2) to crossline near-nadir (Class 1) data were conducted daily to ensure that no systematic errors were introduced and to identify potential problems with the survey system. Comparisons were conducted using grids at the same resolution as the final survey, per HSSD Section 5.2.4.2. 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. Depth data compared were depths derived from the CUBE algorithm. 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 to provide an analysis of the repeatability of the multibeam data system. The Frequency Distribution Tool could be run on a subarea of any loaded 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 were also compared against the calculated maximum Total Vertical Uncertainty (TVU), and are presented in each sheet's DR.

D.1.5.2 Junctions

Junction analysis was conducted with survey sheets assigned in the Project Instructions (H13507, H13508, H13510, H13342, and H13343) and sheets for this project, where the data have been fully processed when applicable. For junction analysis, the current data were binned at appropriate grid resolution using the CUBE algorithm. For the assigned prior junction sheets, BAG files were downloaded from the NCEI website.
For H13510 a CSAR grid was provided from NOAA, which Leidos used for Junctions to this sheet. For comparisons between sheets acquired in OPR-E347-KR-22, comparisons were conducted from the final deliverable CUBE surface; stored from the PFM or BAG. Details regarding the resolution of the sheet to sheet junctions are listed within each sheet's DR.

D.1.5.3 Platform to Platform

Two platforms were used for hydrographic survey operations on OPR-E347-KR-22, the R/V Sea Innovator I and the R/V Oyster Bay II. The R/V Oyster Bay II began survey in the area prior to the arrival of the R/V Sea Innovator I; and continued after the R/V Sea Innovator I completed survey. A comparison of platform to platform depth data is presented within the respective DR for each sheet where both vessels collected coincident data.

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.).

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 Section 5.2.2.2, 200% side scan sonar data are sufficient for disproval of assigned or charted features for Object Detection Coverage Option B. The object detection coverage was verified by generating two separate coverage mosaics, each consisting of either the designated 100% or 200% survey SSS data.

For Complete Coverage Option B surveys, HSSD Section 5.2.2.3 states that 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.

Mosaics were generated in SABER using a time window file, which indicated the valid data, and file lists of the XTF data to build into the mosaic. The XTF file lists were separated by the 100% or 200% coverage mosaic and were independent. All mosaics were generated at 1-meter cell size per HSSD Section 8.2.1. 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 SSS coverage, unless otherwise noted in a sheet's DR.

Each SSS coverage mosaic is delivered as individual georeferenced raster files in floating point GeoTIFF format, per HSSD Sections 8.2.1 and 8.3.3. The GeoTIFF files generated for OPR-E347-KR-22 are referenced to the horizontal datum North American Datum of 1983 (NAD83) 2011 realization 2010 [NAD83(2011)2010.0], UTM Zone 18N.

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. 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 sheet and vessel specific Side Scan Review Log. The times of all noted side scan data gaps were also incorporated into side scan data time window files which was used during the side scan coverage mosaic generation to depict data gaps, as discussed in Section D.2.1.

Data holidays were generally characterized by:
-Dense marine life
-Surface noise (rain, vessel wakes, sea clutter, and/or waves)
-Density layers (refraction)
-Towfish motion (pitch, yaw and heave)
-Electrical noise
-Towfish altitude requirements
-Vessel speed requirements

A Side Scan Review Log for each sheet was maintained throughout 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, 100% or 200% designation, 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.

During side scan data review, the hydrographer used the SABER Contact Review program to evaluate and review each contact. The hydrographer could override automatic measurements of the contact’s length, width, and height or generate new contacts. Selected contacts and pertinent information for each contact were 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 1-meter 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.

Contact Review opens the contact and all surrounding displayed side scan data at full resolution. 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 for fish havens were typically set on each distinct object group. 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, per HSSD Section 6.1.3.5. The XML file was viewed in SABER as a separate data layer along with the PFM grid, and the MBES feature file (CNT). By comparing the bathymetry with the side scan contact data, both datasets were evaluated to determine the significance of an object and the potential need to create additional side scan contacts or bathymetric features. The correlation process updated the CNT file with the type of feature (obstruction, wreck, etc.) and attributes the correlated feature number and least depth into the XML file, which is then used to generate the Feature Correlator Sheets.

Side scan contact images were generated through SABER and are delivered for each sheet under the “HXXXXX/Processed/Multimedia” folder on the delivery drive, the images are also referenced in the Side Scan Sonar Contacts S-57 file NOAA Extended Attribute “images” field. The Feature Correlator Sheet for each feature also includes a maximum of two SSS contact images when correlated to the feature, the Feature Correlator Sheets are referenced in the S-57 Final Feature File NOAA Extended Attribute “images” field.

Per HSSD Section 8.2.2, Leidos generated an S-57 file to represent the final SSS contacts for each sheet; represented as the S-57 feature object cartographic symbol ($CSYMB). 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. Positions within the XTF were in NAD83 datum; SABER converted the positions for each contact to WGS84 datum to populate the S-57. Final contacts were attributed per HSSD Section

6.1.3.4. 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. Per HSSD Section 6.1.3.5, the “remarks” field was used to designate whether or not the contact was correlated to a bathymetric feature. Leidos attributes final charting recommendations within the Final Feature File S-57.

E. Approval Sheet

This Data Acquisition and Processing Report (DAPR), Leidos Document Number 22-TR-020, applies to hydrographic project OPR-E347-KR-22. Data acquisition are complete, and survey data were collected from September 2022 through May 2023. Additional project specific clarifications and guidance are located in Project Correspondence.

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 Survey Specifications and Deliverables, Project Instructions, and Statement of Work.

The survey data meets or exceeds requirements as set forth in the Hydrographic Survey 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	Cheif Hydrographer	07/17/2023	Paul Donaldson:A01410C00000186AE85E8E60006097C Digitally signed by Paul Donaldson:A01410C00000186AE85E8E60006097C Date: 2023.07.17 11:52:57 -04'00'
Alex T. Bernier	Lead Hydrographer	07/17/2023	Alex T. Bernier Digitally signed by Alex T. Bernier Date: 2023.07.17 12:11:57 -04'00'
Bridget W. Bernier	Data Processing Manager	07/17/2023	Bridget Bernier:A01410D00000186FFAF1CC60003D152 Digitally signed by Bridget Bernier:A01410D00000186FFAF1CC60003D152 Date: 2023.07.17 12:12:53 -04'00'
Erin Markham	Lead Hydrographer	07/17/2023	Erin Markham: A01410D00000184D0A210B3000AE99E Digitally signed by: Erin Markham: A01410D00000184D0A210B3000AE99E DN: CN = Erin Markham: A01410D00000184D0A210B3000AE99E C = US O = Leidos OU = Leidos Date: 2023.07.17 12:39:16 -04'00'
Dorena S. Vogel	Lead Hydrographer	07/17/2023	Dorena S. Vogel Digitally signed by: Dorena S. Vogel DN: CN = Dorena S. Vogel email = vogelds@leidos.som C = US O = Leidos Date: 2023.07.17 12:34:35 -04'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	OPR-E347-KR-22_DAPR_Appendices.pdf
Sound Speed Sensor Calibration	OPR-E347-KR-22_DAPR_Appendices.pdf
Vessel Offset	OPR-E347-KR-22_DAPR_Appendices.pdf
Position and Attitude Sensor Calibration	OPR-E347-KR-22_DAPR_Appendices.pdf
Echosounder Confidence Check	OPR-E347-KR-22_DAPR_Appendices.pdf
Echosounder Acceptance Trial Results	OPR-E347-KR-22_DAPR_Appendices.pdf

Additional Report	***File***
Data Processing Flow Diagrams	OPR-E347-KR-22_DAPR_Appendices.pdf
GSF Flag Mapping to CARIS Flag Codes	OPR-E347-KR-22_DAPR_Appendices.pdf