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

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	OPR-K306-TJ-20
Time Frame:	September - October 2020

LOCALITY

State(s):	Louisiana
General Locality:	Flower Garden Banks National Marine Sanctuary

2020

CHIEF OF PARTY
CDR Briana Welton Hillstrom, NOAA

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NOAA Ship *Thomas Jefferson*
Chief of Party: CDR Briana Welton Hillstrom, NOAA
Year: 2020
Version: 1.0
Publish Date: 2020-10-20

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAA Ship THOMAS JEFFERSON (WTEA)

Vessel Name	NOAA Ship THOMAS JEFFERSON (WTEA)	
Hull Number	S222	
Description	S222 is a steel hulled hydrographic survey ship built by Halter Marine, Inc., Moss Point, MS.	
Dimensions	*LOA*	63.4m
	Beam	13.7m
	Max Draft	4.6m
Most Recent Full Static Survey	*Date*	2016-09-01
	Performed By	The IMTEC Group, Ltd.

Figure 1: Thomas Jefferson underway from the starboard view.

A.1.2 Hydrographic Survey Launch 2904 (HSL 2904)

Vessel Name	Hydrographic Survey Launch 2904 (HSL 2904)	
Hull Number	2904	
Description	HSL 2904 is an aluminum hulled hydrographic survey launch built in 2017 by Willard Marine, Inc. HSL 2904 is equipped to collect bathymetric data, side scan imagery, and water column profiles.	
Dimensions	*LOA*	8.5m
	Beam	3m
	Max Draft	1.2m
Most Recent Full Static Survey	*Date*	2020-01-01
	Performed By	Kevin Jordan, National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch

Figure 2: 2903 and 2904 returning to S222

Figure 3: 2904 conducting survey ops

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM710

The Kongsberg EM710 is a high resolution MBES system. The system is capable of operating at frequencies from 70 to 100 kHz and can provide across-track swath width up to 5.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 2000 meters. For hydrographic survey collection, the EM710 is set to a max angle of 60 degrees with angular coverage set to Auto. The beam spacing is set to high density equal distant to obtain max swath width when operating in any depth. Dual swath mode is set to Dynamic. Dynamic mode is selected because it allows the along side angle between the two transmit fans to be determined based on the vessel speed, ping rate, and depth in order to provide a uniform along ship sampling of the sea floor.

The Sonar acceptance report of the THOMAS JEFFERSON EM710 can be found in the appendices.

<table>
<tr><td>Manufacturer</td><td colspan="2">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="2">EM710</td></tr>
<tr><td>Inventory</td><td>S222</td><td>
<table>
<tr><td>Component</td><td>Processing Unit</td><td>Work Station</td><td>Transducer</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>EM710</td><td>EM710</td><td>EM710</td><td>EM710</td></tr>
<tr><td>Serial Number</td><td>241</td><td>CZC3407HFV</td><td>235</td><td>172</td></tr>
<tr><td>Frequency</td><td>70-100 kHz</td><td>70-100 kHz</td><td>70-100 kHz</td><td>70-100 kHz</td></tr>
<tr><td>Calibration</td><td>2020-06-09</td><td>2020-06-09</td><td>2020-06-09</td><td>2020-06-09</td></tr>
<tr><td>Accuracy Check</td><td>2020-06-09</td><td>2020-06-09</td><td>2020-06-09</td><td>2020-06-09</td></tr>
</table>
</td></tr>
</table>

A.2.1.2 Kongsberg EM2040

The Kongsberg EM2040 MBES is a high resolution shallow water MBES. The system is capable of operating at 200, 300, or 400 kHz frequencies, can provide across-track swath width up to 5.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 600 meters.

The EM2040 is operated at the 300 kHz frequency for normal shallow water operations.

For hydrographic survey collection, the EM2040 is set to a max angle of 60 degrees with angular coverage set to Auto. The beam spacing is set to high density equal distant to obtain max swath width when operating in any depth. Dual swath mode is set to Dynamic. Dynamic mode is selected because it allows the along side angle between the two transmit fans to be determined based on the vessel speed, ping rate, and depth in order to provide a uniform along ship sampling of the sea floor. The frequency of the EM2040 is typically set to

300 kHz for normal survey operations, and will shift to 400 kHz for shallow water data collection. Pulse type set to auto with FM disabled.

Components of the EM2040 include a sonar head, a processing unit, and a hydrographic workstation. Motion sensor and positioning data from the POSMV system, with sound speed profile data being input to the EM 2040 via separate sound speed profiling equipment. All echo sounder electronics are contained in the sonar head which is interfaced to the processing unit via GBit Ethernet. The processing unit also supplies 48 VDC power via the same cable. Operator control, data quality inspection, and data storage is handled by the hydrographic workstation running SIS software.

The Sonar Acceptance Reports for the EM2040 on HSL 2904 can be found in the appendices.

<table>
<tr><td>Manufacturer</td><td colspan="6">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="6">EM2040</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">2904</td><td>Component</td><td>Processing Unit</td><td>Work Station</td><td>Transducer</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>EM2040</td><td>EM2040</td><td>EM2040</td><td>EM2040</td></tr>
<tr><td>Serial Number</td><td>40139</td><td>CZC7468666</td><td>2828</td><td>3939</td></tr>
<tr><td>Frequency</td><td>200-400kHz</td><td>200-400kHz</td><td>200-400kHz</td><td>200-400kHz</td></tr>
<tr><td>Calibration</td><td>2020-02-26</td><td>2020-02-26</td><td>2020-02-26</td><td>2020-02-26</td></tr>
<tr><td>Accuracy Check</td><td>2020-02-26</td><td>2020-02-26</td><td>2020-02-26</td><td>2020-10-20</td></tr>
</table>

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

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 Corporation POS MV 320 Version 5

The Applanix POS MV 320 Version 5 (Position and Orientation System for Marine Vessels, hereafter 'POS MV v5') is a GNSS Inertial Navigation System that provides high frequency and highly accurate vessel trajectory (both navigation/position and attitude/orientation) data. The system incorporates data from an Inertial Motion Unit (IMU) and dual multi-constellation GNSS receivers. Advanced proprietary Kalman Filtering techniques are used to provide a blended navigation and trajectory solution in real-time that is both highly accurate and reliable. The POS MV v5 also computes vessel heave (both instantaneous and 'delayed' heave values). The POS MV v5 system is integrated with all platform acquisition systems. Data from the POS MV v5 is applied to echosounder data in real-time and logged for post-processing/archiving.

The POS/ MV generates attitude data in three axes (roll, pitch, and heading) to an accuracy of 0.02° or better. Real-time heave measurements supplied by the POS/MV maintain an accuracy of 5% of the measured vertical displacement or 05 cm (whichever is greater) for vertical motions less than 20 seconds in period. The standard practice on THOMAS JEFFERSON is to configure the Heave Bandwidth filter with a damping coefficient of 0.707. The standard practice is to apply a high pass filter that is determined by the longest swell period encountered on the survey grounds. The POS MV v5 is also calculates a 'delayed heave' (Applanix labels this 'TrueHeave') value. The Applanix delayed heave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. Applanix delayed heave measurements maintain an accuracy of 2% of the measured vertical displacement or 2 cm (whichever is greater) for vertical motions less than 20 seconds in period. Delayed heave measurements are logged and applied to MBES data in post processing.

A graphical user interface provides visual representations and summary statistics of data quality in real-time. Performance parameters are monitored by acquisition hydrographers in real-time and checked against HSSD requirements.

Position and trajectory data from the POS MV v5 system is applied in both real-time and post-processed applications. Navigation and attitude data is applied to all echosounder data in real-time. Raw data from the POS MV v5 can also be post-processed after acquisition to achieve trajectory solutions that are more accurate than those achieved in real-time by using forward/backward processing methods. Post-processing is conducted using the Applanix POSPac MMS software suite. Post-processing methodology is described elsewhere in this document.

Position and Attitude data is recorded daily in 20 minute file increments to a computer at 100Hz through an Ethernet connection.

<table>
<tr><td>Manufacturer</td><td colspan="4">Applanix Corporation</td></tr>
<tr><td>Model</td><td colspan="4">POS MV 320 Version 5</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">S222</td><td>Component</td><td>IMU</td><td>PCS</td></tr>
<tr><td>Model Number</td><td>LN200 (IMU2)</td><td>V5</td></tr>
<tr><td>Serial Number</td><td>1047</td><td>6497</td></tr>
<tr><td>Calibration</td><td>2020-06-09</td><td>2020-06-09</td></tr>
<tr><td rowspan="4">2904</td><td>Component</td><td>IMU</td><td>PCS</td></tr>
<tr><td>Model Number</td><td>LN200 (IMU2)</td><td>V5</td></tr>
<tr><td>Serial Number</td><td>293</td><td>8927</td></tr>
<tr><td>Calibration</td><td>2020-02-26</td><td>2020-02-26</td></tr>
</table>

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

GPS equipment was not utilized for data acquisition.

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 MVP100 Moving Vessel Profiler (MVP)

S222 is equipped with a Rolls-Royce Group Brooke Ocean MVP100 Moving Vessel Profiler (MVP) that is now owned by AML Oceanographic. The MVP system consists of a sensor towfish, a conductor/tow cable, a computer controlled high speed hydraulic winch, and a cable metering system. A Conductivity-Temperature-Depth (CTD) or direct-read sound speed sensor is housed in the sensor towfish and interfaced with the ship acquisition system via the conductor/tow cable. The MVP system provides a means of collecting full water-column data while S222 remains underway. The MVP system on S222 has ~150m of cable and can be used to take water-column profiles of approximately 100m in depth at speeds of approximately 10 kts.

<table>
<tr><td>Manufacturer</td><td>AML Oceanographic</td></tr>
<tr><td>Model</td><td>MVP100 Moving Vessel Profiler (MVP)</td></tr>
<tr><td>Inventory</td><td><table><tr><td>S222</td><td><table>
<tr><td>Component</td><td>MVP System</td></tr>
<tr><td>Model Number</td><td>MVP 100</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Calibration</td><td>2020-01-23</td></tr>
</table></td></tr></table></td></tr>
</table>

A.6.2 CTD Profilers

A.6.2.1 AML Oceanographic AML MVP-X

The AML MVP-X is a multi-parameter sensor designed specifically for use with the AML Moving Vessel Profiler (MVP) models. The MVP-X is highly configurable and is compatible with all AML Xchange (tm) oceanographic sensors. The MVP-X configuration used on S222 includes conductivity, temperature and pressure sensors: the conductivity sensors provide a sensor range of 0-90 mS/cm, a resolution of 0.001 mS/cm, with an accuracy of plus/minus 0.01 mS/cm; the temperature sensors provide a sensor range of -5 to +45 Deg C, a resolution of 0.001 Deg C, with an accuracy of plus/minus 0.005 Deg C; the pressure sensors provide a sensor range of 0 to 1000 dBar, a resolution of 0.02% of measurement, with an accuracy of 0.05% of measurement. The main instrument housings on the MVP-X units are rated for operation at pressures up to 6000 dBar.

Manufacturer	AML Oceanographic		
Model	AML MVP-X		
Inventory	*Component*	Probe	Probe
	Model Number	AML MVP-X	AML MVP-X
	Serial Number	9001	9006
	Calibration	2020-01-23	2019-03-27

A.6.2.2 Sea-bird Electronics SBE 19plus V2

The Sea-Bird Electronics SBE 19plus V2 SeaCAT profiler measures conductivity, temperature, and depth (CTD) in marine and/or freshwater environments. The SBE 19plus V2 is rated for use at depths of up to 600 meters and is capable of sampling at a rate of 4 measurements per second. CTD values are used to calculate the speed of sound through the water column.

Sea-Bird Electronics SBE 19plus V2 Conductivity, Temperature, and Depth (CTD) Profilers are used on HSL 2904 to collect vertical sound speed profiles. The speed of sound is calculated from temperature, salinity, and pressure measurements. Temperature is measured directly. Salinity is calculated from measured electrical conductivity. Depth is calculated via strain gauge pressure sensor. The system is configured for a sampling rate of 0.5 seconds. CTD equipment is deployed over the side of the launches by hand or over the side of the Thomas Jefferson by winch . The CTD is first soaked for 2 minuted before letting the device free fall to the bottom and then recovered at a rate roughly equal to 1 meter per second.

Manufacturer	Sea-bird Electronics	
Model	SBE 19plus V2	
Inventory	*Component*	CTD
	Model Number	19plus V2
	Serial Number	19P33589-4487
	Calibration	2020-02-18
	Component	CTD
	Model Number	19plus
	Serial Number	19P36399-4630
	Calibration	2020-02-11

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne Reson Reson SV-71

The Reson SVP-71 is a direct-read sound velocity measurement device. The SVP devices obtain sound speed measurements by directly measuring the travel time of sound pulses along a set 125 mm transmission path. The SVP systems are capable of reading sound speeds from 1350 to 1800 m/s with a resolution of 0.01 m/s (±0.15m/s) at a sampling rate of 20 Hz.

Reson SVP-71 sensors collect the speed of sound at the face of the Kongsberg EM2040 transducers on HSL 2904. The sensors are bolted to the mounting sleds near the face of the transducer on each launch. The speed of sound is measured directly using a direct path echosounding sensor. The SVP-71 is integrated with the Kongsberg EM2040.

Manufacturer	Teledyne Reson		
Model	Reson SV-71		
Inventory	*2904*	*Component*	Probe
		Model Number	SVP-71
		Serial Number	1213050
		Calibration	2018-09-03

A.6.3.2 Valeport Limited MODUS SVS Thruhull

The sound speed sensor used in the system is a direct-read 'time of flight' sound speed sensor. The Modus models used aboard S222 use a 100mm measurement path and include temperature sensors. The sound speed sensor can measure sound in fresh water or marine environments with a measurement range of 1400-1600 m/s, at a resolution of 0.001 m/s, with an accuracy of ± 0.03 m/s. The thru-hull port where the sound speed sensor is deployed is located adjacent and aft of the transducer fairing.

Manufacturer	Valeport Limited			
Model	MODUS SVS Thruhull			
Inventory	*S222*	*Component*	Probe	Probe
		Model Number	065101	065101
		Serial Number	33711	33747
		Calibration	2019-02-27	2020-01-08

A.6.4 TSG Sensors

A.6.4.1 Seabird SBE 45

The externally powered SBE 45, typically mounted near the ship's seawater intake, accurately determines sea surface temperature and conductivity from underway vessels. Measured data and derived variables (salinity, sound velocity) are output in real-time in engineering units.

Manufacturer	Seabird		
Model	SBE 45		
Inventory	*S222*	*Component*	Sensor
		Model Number	SBE 45
		Serial Number	0491
		Calibration	2020-02-12

A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Caris	HIPS&SIPS	11.3.5	Processing
Caris	BASE Editor	5.3	Processing
NOAA	Pydro (ie: Charlene, QC tools, XmlDR, SHAM, transmission letter, Sound Speed Manager)	19.4	Processing
HYPACK - A Xylem Brand	HYPACK	2020	Acquisition
Applanix Corporation	POSPac MMS	8.4	Processing
Applanix Corporation	POSView	10.0	Acquisition
Applanix Corporation	POSView	10.2	Acquisition
ESRI, Inc.	ArcGIS	10.6.1	Processing
QPS, Inc	FMGT	7.9.3	Processing
Kongsberg	Seafloor Information System (SIS)	4.3.2	Acquisition

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

Offsets for S222 are derived from a full survey performed by Kongsberg USA-contracted personnel and have been verified by Hydrographic Systems and Technology Branch (HSTB) personnel. All offsets are tracked and updated as needed. Offset values are known in the vessel reference frame, the IMU reference frame, and the Kongsberg reference frame. Offset values for the Kongsberg MBES systems are entered into SIS and the ship's Caris HIPS Hydrographic Vessel File (HVF), with the exception of the orthogonal offsets between the primary GNSS sensor antenna and the Applanix IMU. The offset between the primary GNSS antenna and the IMU is applied to the POS MV. The POS MV provides navigation and attitude data in the IMU reference frame at the IMU reference point. All other offsets are applied to the data during the SVP or Merge processing steps in CARIS HIPS.

The offset between the primary GNSS antenna and the IMU for S222 is derived by a lever arm calibration conducted with Applanix POSPac software during the annual Hydrographic System Readiness Review (HSRR). The lever arms derived are X = -9.937, Y = 1.327, and Z = -22.462. These offsets were used for acquisition for the dates between 7/19/2020 to UTC 0000 8/23/2020. A motion artifact was observed within data collected for sheets H13391, H13393, and H13394. To diagnose the apparent motion artifact, the lever arms were reverted to the field season 2019 values of X = -9.937, Y = 1.389, and Z = -22.421. The motion artifact appears to be an induced heave artifact. This artifact was not observed in 2019 and it was suspected that it was due to the change of the offset between the primary GNSS antenna and the IMU. 2019 field season values did not reduce the motion artifact.

Offsets for HSL 2904 are derived from a full vessel survey performed by NGS personnel. Offset values are known in the vessel reference frame, the IMU reference frame, and the Kongsberg reference frame. Offset values for the Kongsberg MBES systems are entered into POS/MV, with the exception of the orthogonal offsets between the transducer and receiver. These values are entered into SIS and the HSL's Caris HVF. The offset between the primary GNSS antenna and the IMU is applied within the POS/MV. The reference point for the HSL's is the Kongsberg EM2040 transducer face. The POS/MV provides navigation and attitude data in the Kongsberg reference frame at the transducer face reference point. All other offsets are applied to data during the SVP or Merge processing steps in CARIS HIPS.

The offset between the primary GNSS antenna and the IMU for HSL 2904 is derived by a lever arm calibration conducted with Applanix POSPac software during the annual Hydrographic System Readiness Review (HSRR). The lever arms derived are X = -0.930, Y = -0.947, and Z = -4.188.

Offsets are applied to side scan sonar data during the Compute Towfish Navigation step.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the Appendices to this report. HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere and include all of the requested values for the DAPR necessary to reproduce an HVF.

For a detailed look at the applied lever arms and mounting angles see the Appendices of this report.

B.1.1.1 Vessel Offset Correctors

Vessel	S222			
Echosounder	Kongsberg EM710			
Date	2020-01-01			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
Offsets	*MRU to Transducer*	*x*	2.360 meters	0.020 meters
Offsets	*MRU to Transducer*	*y*	-0.455 meters	0.020 meters
Offsets	*MRU to Transducer*	*z*	5.001 meters	0.020 meters
Offsets	*MRU to Transducer*	*x2*	2.474 meters	0.020 meters
Offsets	*MRU to Transducer*	*y2*	-1.727 meters	0.020 meters
Offsets	*MRU to Transducer*	*z2*	5.000 meters	0.020 meters
Offsets	*Nav to Transducer*	*x*	1.033 meters	0.020 meters
Offsets	*Nav to Transducer*	*y*	9.482 meters	0.020 meters
Offsets	*Nav to Transducer*	*z*	27.463 meters	0.020 meters
Offsets	*Nav to Transducer*	*x2*	1.147 meters	0.020 meters
Offsets	*Nav to Transducer*	*y2*	8.210 meters	0.020 meters
Offsets	*Nav to Transducer*	*z2*	27.462 meters	0.020 meters
Offsets	*Transducer Roll*	*Roll*	-0.252 degrees	
Offsets	*Transducer Roll*	*Roll2*	-0.177 degrees	

Vessel	S222			
Echosounder	Kongsberg EM710			
Date	2020-08-23			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	2.360 meters	0.020 meters
		y	-0.455 meters	0.020 meters
		z	5.001 meters	0.020 meters
		x2	2.474 meters	0.020 meters
		y2	-1.727 meters	0.020 meters
		z2	5.000 meters	0.020 meters
	Nav to Transducer	*x*	0.971 meters	0.020 meters
		y	9.482 meters	0.020 meters
		z	27.422 meters	0.020 meters
		x2	1.085 meters	0.020 meters
		y2	8.210 meters	0.020 meters
		z2	27.421 meters	0.020 meters
	Transducer Roll	*Roll*	-0.252 degrees	
		Roll2	-0.177 degrees	

Vessel	2904			
Echosounder	Kongsberg EM2040			
Date	2020-01-01			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.188 meters	0.020 meters
		y	0.170 meters	0.020 meters
		z	0.543 meters	0.020 meters
		x2	-0.144 meters	0.020 meters
		y2	0.061 meters	0.020 meters
		z2	0.529 meters	0.020 meters
	Nav to Transducer	*x*	0.924 meters	0.020 meters
		y	0.918 meters	0.020 meters
		z	4.219 meters	0.020 meters
		x2	0.622 meters	0.020 meters
		y2	0.809 meters	0.020 meters
		z2	4.205 meters	0.020 meters
	Transducer Roll	*Roll*	0.060 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

Side Scan Sonar was not utilized for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

Static draft is measured on the S222 using a Sutron Bubbler system. The orifice was surveyed into the IMU reference frame and a waterline height was calculated. A common waterline for the ship when fully loaded with fuel and ballasted normally is approximately 35cm below the reference point of the ship, but the waterline may change by as much as +/- 30cm over the course of a field season.

The static draft is not applied to soundings for ERS Surveys.

The waterline for S222 is measured at least weekly. When feasible, waterline measurements are taken before and after fueling or ballasting of the ship. The values are kept in a static draft log and periodically updated in the HVF. Once applied in the HVF, all affected lines have SVP re-applied and are then merged so that the updated waterline measurements will be applied.

The waterline for HSL platforms is measured using physical measurements from the waterline of the vessel to physical known benchmarks.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

B.2.1.1 Static Draft Correctors

Vessel		S222	S222	S222	S222	S222	S222	2904
Date		2020-01-01	2020-07-19	2020-07-22	2020-07-27	2020-07-28	2020-08-08	2020-01-01
Loading		0.1 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters
Static Draft	*Measurement*	0.451 meters	0.339 meters	0.358 meters	0.425 meters	0.509 meters	0.485 meters	-0.670 meters
	Uncertainty	0.03 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters	0.03 meters

B.2.2 Dynamic Draft

Dynamic draft for all platforms was measured using the Post Processed Kinematic GPS method outlined in section 1.4.2.1.2.1 of NOAA's FPM. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water. Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVF).

In ERS surveys (those that use recorded GPS heights corrected via a VDatum SEP model to achieve tidal datum) the dynamic draft correction is not applied to the soundings.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

B.2.2.1 Dynamic Draft Correctors

Vessel	S222		2904	
Date	2020-01-01		2020-02-25	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*
	0.00	0.00	0.00	0.00
	0.50	0.00	0.50	-0.01
	1.00	0.04	1.00	0.00
	1.50	0.06	1.50	0.01
	2.00	0.05	2.00	0.03
	2.50	0.04	2.50	0.04
	3.00	0.03	3.00	0.05
	3.50	0.03	4.00	0.05
	4.00	0.05	4.50	0.03
	4.50	0.11	5.00	-0.00
	5.00	0.22	5.50	-0.04
	5.50	0.29	6.00	-0.10
	6.00	0.38	6.50	-0.17
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.50	0.04	0.50	0.02

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

NOAA Ship THOMAS JEFFERSON (S222) conducts MBES calibration tests during annual HSRR activities for each individual multibeam system on the ship and her launches.

The procedure used follows that outlined in section 1.5.5.1 of the Field Procedures Manual dated April 2014. Timing bias was determined using the method of running the same line at different speeds. Pitch and yaw bias was determined using a target on the sea floor. Finally, roll bias was determined using the standard flat bottom method. Offset values for all platforms were derived using Caris' patch testing tools during annual HSRR activities.

S222 patch test values are applied within Kongsberg Sea floor Information System (SIS) at acquisition. HSL 2904 patch test values are applied within POS/MV software at acquisition.

A -0.10° roll offset was applied to data form S222 acquired within the dates of 07/19/20209-08/05/2020. These additional roll offsets were applied via Transducer 1 within the CARIS HVF corrected in post processing when correcting for sound velocity. These additional roll values were added to SIS offsets and subsequently set as zero within the HVF for data acquired after 08/05/2020.

All calibration reports can be found in the Appendix Folder.

B.3.1.1 System Alignment Correctors

Vessel	S222		
Echosounder	Kongsberg EM710		
Date	2020-06-09		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.001 seconds
	Navigation Time Correction	0.00 seconds	0.001 seconds
	Pitch	0.00 degrees	0.02 degrees
	Roll	0.00 degrees	0.02 degrees
	Yaw	0.00 degrees	0.02 degrees
	Pitch Time Correction	0.00 seconds	0.001 seconds
	Roll Time Correction	0.00 seconds	0.001 seconds
	Yaw Time Correction	0.00 seconds	0.001 seconds
	Heave Time Correction	0.00 seconds	0.001 seconds

Vessel	2904		
Echosounder	Kongsberg EM2040		
Date	2020-01-01		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.00 seconds	0.001 seconds
	Navigation Time Correction	0.00 seconds	0.001 seconds
	Pitch	0.00 degrees	0.02 degrees
	Roll	0.00 degrees	0.02 degrees
	Yaw	0.00 degrees	0.02 degrees
	Pitch Time Correction	0.00 seconds	0.001 seconds
	Roll Time Correction	0.00 seconds	0.001 seconds
	Yaw Time Correction	0.00 seconds	0.001 seconds
	Heave Time Correction	0.00 seconds	0.001 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

All multibeam data on is logged using Kongsberg Sea floor Information System (SIS) in the .all file format.

During acquisition aboard NOAA Ship THOMAS JEFFERSON and HSL 2904 the hydrographer:

- Monitors the SIS interface for errors and data quality

- Monitors the SIS interface for indication of sound speed changes requiring a cast, and conducts casts as necessary

- Monitors the Hysweep interface in HYPACK

- Monitors the vessel speed and requests the bridge to adjust as necessary to ensure density and coverage specifications are met

Data Processing Methods and Procedures

One work flow exists and was used during acquisition.

Applanix RTX with Kongsberg EM2040 or EM710:

1) Create SBET and RMS files in POSPac MMS.
2) Convert raw .all data to Caris HDCS format
3) Load Delayed Heave - Delayed heave is processed with a 0.014s offset for S222 to properly align the delayed heave with the timing offset that is applied in SIS for motion delay.
4) Import ancillary data: SBET and RMS
5) Apply sound speed correctors
6) Compute GPS Tides using the provided VDatum SEP model.
7) Merge; use GPS Tides.
8) Compute Total Propagated Uncertainty (TPU)
9) Create a Combined Uncertainty and Bathymetry Estimator (CUBE) surface
10) If necessary, create a holiday line plan.

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

After initial processing, the bathymetric data is gridded into BASE surfaces using the Combined Uncertainty and Bathymetry Estimator (CUBE) algorithm. This type of surface calculates a horizontal and vertical uncertainty for each sounding, derived from the combined uncertainty from each of the sensors that contributes data to the sounding (e.g water levels, tide zoning, attitude sensor error, navigation sensor horizontal position error, and sound velocity profile error). Individual soundings are then propagated to grid nodes, which takes on a depth value as well as an uncertainty value based on all the soundings that contribute to the node. The influence of a sounding on a grid node is limited to 0.707 times the grid resolution.

C.1.4.2 Depth Derivation

Filters are used on a case-by-case basis as determined by the hydrographer. Refer to the Descriptive Report for more information. Gridding parameters and surface computation algorithms comply with the HSSD and are described above.

C.1.4.3 Surface Computation Algorithm

MBES data is gridded using the CUBE algorithm. Resolution is dictated by the Project Instructions, as well as section 5.2.2 of the HSSD. The disambiguation method used is always Density and Local. The settings used for Capture Distance Scale, Horizontal Error Scale, and Capture Distance Minimum are those listed in section 4.2.1.1.1.1 of the FPM. After creation, Uncertainty and CUBE surfaces go through a quality control process. During this process, the Depth, Uncertainty, Standard Deviation, and Density child layers are examined for compliance with NOAA specifications. After the surfaces pass quality control, they are finalized. Uncertainty values for finalized surface come from the greater of either Uncertainty, or Standard Deviation.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

MBES backscatter data are logged via SIS and are included in the MBES files (.all format) by default.

The absorption coefficient depends upon depth, water temperature, salinity and frequency. A correct value is important with respect to the validity of the bottom backscatter data measured by the system.

The normal incidence sector [Angle from nadir (deg)] which defines the angle at which the bottom backscatter can be assumed not to be affected by the strong increase at normal incidence. For seabed imaging, it is important to adjust this angle so that a minimum of angle dependent amplitude variation is seen. The value for this parameter is kept at 15 degrees unless otherwise documented.

For Beam Intensity, Lambert's Law is selected within SIS.

Data Processing Methods and Procedures

All acquired backscatter data are processed into a mosaic and delivered to AHB. All processing of backscatter is done using the FMGT (7.9.2) module of the QPS Fledermaus software package in accordance with OCS standard data processing methods.

The following is the general work flow for creating backscatter imagery:

- A new project is created for each sheet and each vessel and each sonar frequency. Meta data within the .all files ensures that sonar-specific characteristics are captured during mosaic processing.

- Vessel parameters are set, and allow the hydrographer to set configuration for each frequency and pulse length in order to calibrate slight differences in decibel levels. This produces a smoother, less patchwork appearance of backscatter mosaics between each frequency and pulse length. Parameter values may be determined by running a calibration line in the same direction with each possible combination of vessel, frequency, and pulse length.

- Lines are imported into FMGT. One mosaic is created per boat and frequency (70-100kHz, 200kHz, 300kHz, and or 400kHz), meaning multiple mosaics are created, one for each frequency if multiple frequencies are used during acquisition.

- Create a mosaic. Crosslines are not needed in the mosaic and are deselected. Mosaic gridding resolution is set to 1m. The product is exported as a floating point GeoTIFF grid with a value for no data set to -9999.

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

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

DGPS data was not acquired.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

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

Raw GNSS-INS observables data are logged through POSView for S222 and HSL 2904.

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

NOAA Ship THOMAS JEFFERSON reduces all data to chart datum via Ellipsoidally Referenced Survey (ERS) work flows for all surveys.

GPS Tides:

The ‘Compute GPS Tides’ process in Caris HIPS is the primary means by which bathymetric data is reduced to chart datum. The Compute GPS Tides step references all MBES data to an ellipsoid and then applies a separation model to the ellipsoidally referenced data to achieve reduction to chart datum. The separation model is an XYZ surface that represents the difference between the ellipsoid and chart datum for the a given geographic area. The XYZ separation model used for typical NOAA work flows is delivered as a Caris CSAR file and represents the difference between the WGS84 ellipsoid and MLLW at a given location. All separation models for waters in which THOMAS JEFFERSON operates are derived from the NGS Vertical

Datum (VDatum) program. Separation models are usually generated, approved and disseminated by HSD Ops.

GNSS positioning methods employed to meet ERS specifications include the methods described below:

Raw GNSS-INS observables data are logged through POSView can be post-processed in POSPac MMS to provide a trajectory solution that can be applied to MBES data in CARIS HIPS. Post-Processed Trimble CenterPoint real-time extended is the standard practice for S222 and HSL 2904.

Inertially aided Fusion Post-Processed real-time extended:

During post-processing, horizontal positioning can be shifted to an Inertially aided Fusion Post-Processed real-time extended (Trimble PP-RTX) solution. The solution is created by combining GPS/GNSS satellite ephemeris and clock data with position information downloaded from a network of Continually Operating Reference Stations (CORS). The resulting position data is corrected for the effects of atmospheric interference on the GPS signal. The corrected GPS position is then combined with the vessel's inertial data using the POSPac MMS program to create a Smoothed Best Estimate of Trajectory (SBET). The resulting position can be used to apply higher quality navigation information to the processed data.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

As described in Section A.5 of this document.

Data Processing Methods and Procedures

As described in Section C.3 of this document.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

S222 uses an AML MVP-X Probe installed inside an MVP free-fall fish to acquire sound speed profiles. Profiles aboard the ship are generally acquired at 30 - 90 minute intervals. Cast frequency is increased when the comparisons show significant variability. Sampling intervals are adjusted to ensure spatial variability or if there is suspicion of sudden changes in the water-column.

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a towfish containing conductivity, temperature and depth sensors. The fish is towed behind S222 in a ready position that is marked by messengers attached to the tow cable. The towfish is typically deployed at a ready depth that is approximately the same depth of the ship MBES transducers. Deployment depth is a function of water depth. The towfish descends at the rate of freefall when deployed. Towfish freefall is automatically stopped once a specified depth limit is met and the drag forces on the fish cause it to rise toward the surface due to the ship's forward motion. The cable slack is then pulled in by the winch to the ready towing position.

The approximate maximum depth S222s MVP is capable of at this time is 100m. The depths found within the project area often exceeded this depth. In these areas frequent (1/hr) MVP casts were appended to deep CTD casts taken approximately 1/24hrs.

The following procedure is followed when conducting manual CTD casts with the SBE 19plus or 19plus V2: The instrument is lowered into the water and submerged just below the water's surface for about 2 minute to allow air to escape the salinity cell. The instrument is lowered at the rate of free fall. The instrument is lowered slowly (in some cases, much less than 1 meter/second) through the first 5-10 meters of water in order to accurately sample the sound speed for areas with lenses of fresh water or other complex sound speed variation near the surface.

HSL 2904 uses Sea-Bird SBE 19plus CTDs to collect sound speed profiles. Casts are generally taken at 1-4 hour intervals. Casts are also conducted when changing survey areas or when a change of weather, tide, or current warrant. The launch crew also monitors the real time display of the Reson SVP-71 sound velocity probe for significant changes in the surface sound velocity.

Data Processing Methods and Procedures

Downloading and processing of sound speed data is performed using Sound Speed Manager, part of the HSTB-supplied Pydro 19 program suite. Sound speed values are calculated using the UNESCO equation (Fofonoff and Millard, 1983). Processed profiles are sent to SIS for realtime beam control. In addition, both raw and processed CTD files are archived and submitted to the hydrographic branch as part of the sheet submission package.

All sound velocity profiles for CARIS are concatenated into a vessel-wide and sheet-wide files in order of ascending time and date. These concatenated file(s) are applied to all HDCS data acquired with "Nearest in distance within time (1 Hours)" selected under the "Profile selection Method".

Processed sound speed data data is applied to the MBES data in Caris HIPS.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

S222 uses a Valeport probe to find the speed of sound at the approximate depth of the Kongsberg transducers.

HSL 2904 uses a Reson SV-71 probes to acquire sound speed at it's transducer face.

Sound speed values are applied in real-time to all MBES systems to provide refraction corrections to flat-faced transducers.

The accuracy of each surface sound speed device is checked against the closest CTD data point after every CTD cast.

Data Processing Methods and Procedures

Surface sound speed data are logged directly into Kongsberg raw data files. Surface sound speed data is not typically processed after the time of acquisition.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Total Propagated Uncertainty (TPU) is calculated in Caris HIPS using the 'Compute TPU tool'.

The uncertainty values for each input into the TPU model can come from one of three sources: Real-time, Static, or Vessel. Real-time values are provided from the sensor or processing package (e.g. POSPac RMS values). Static values are those entered manually into the Compute TPU dialog (e.g. tidal zoning uncertainty and sound speed measurement uncertainties). Static values are documented in each Descriptive Report. Vessel values are taken from the HVF if no realtime or static values are available.

Uncertainty values entered into the HVF for the multibeam and positioning systems are derived from manufacturer specifications sheets for each sensor and from values set forth in section 4.2.3.8 and Appendix 4 - Caris HVF Uncertainty Values of the 2014 FPM.

Sound speed static values are derived from the guidance in the FPM, manufacturer specifications and annual calibration results.

Tide correction uncertainty values for the ERS work flow are static values specified in the Project Instructions.

Ellipsoid height uncertainty values for ellipsoid measurements derived from 5P or Trimble PP-RTX work flows are applied as real-time values from RMS files. Kongsberg systems provide uncertainty statistics that are recorded in raw MBES files.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

See included HVFs for information on vessel uncertainty values.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		S222	2904
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		0.50 meters	0.50 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
S222	As discussed above.
2904	As discussed above.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

The following workflow is used to develop and verify features:

- Potentially significant features are initially identified and inspected in Caris HIPS (both MBES and SSS contacts).

- A development area polygon or point feature is exported from HIPS; a line plan is created using HIPS or ArcMap if needed.

- Object Detection level MBES data is collected over all MBES and/or SSS contacts, VBES designated soundings, and all possible shoal areas.

Quality of data is controlled through:

- Real time monitoring during acquisition to ensure that all features are covered by near nadir beams.

- Inspection of the CUBE surface's Density, Standard Deviation, and Uncertainty layers.

- All developments are examined for significance. Objects found to be significant are flagged with a designated sounding, and become part of the Final Feature File.

Data Processing Methods and Procedures

Feature verification begins during initial data processing. Both SSS and MBES data are processed following the conclusion of daily acquisition operations or at regular intervals (typically daily) for continuous ship operations. Significant contacts are identified and noted during initial processing. All significant contacts are then developed using a MBES. When conducting Multibeam surveys, or when reviewing MBES developments over side scan sonar contacts, the least depths over navigationally significant features are flagged as 'designated soundings', then imported into Caris BASE Editor or HIPS. Inside BASE Editor, each significant contact is given an S-57 attribution, and the hydrographer recommends charting action. The final deliverable is a Final Feature File (FFF) in .000 format.

C.8 Bottom Sample Data

Bottom sample data was not acquired.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

All statistics layers generated by the Caris CUBE implementation are used (including uncertainty, hypothesis count, hypothesis strength, and standard deviation) to direct data cleaning.

The Flier Finder function in Pydro QC Tools is used to direct cleaning of potential 'fliers' in the bathymetric surface data.

D.1.2 Designated Sounding Selection

In accordance with HSSD 2020.

D.1.3 Holiday Identification

Holidays are identified primarily through the use of two tools: the QC Tools program included with recent version of Pydro and via standard tools included in ArcGIS (primarily to inspect SSS mosaics). All surfaces are also visually inspected.

D.1.4 Uncertainty Assessment

In accordance with HSSD 2020 using methods described above.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Difference surfaces are conducted in accordance with HSSD 2020 and as outlined in the DR.

D.1.5.2 Junctions

Difference surfaces are conducted in accordance with HSSD 2020 and as outlined in the DR.

D.1.5.3 Platform to Platform

Difference surfaces are conducted in accordance with HSSD 2020 and as outlined in the DR.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Coverage is assessed in accordance with HSSD 2020. Pydro QC Tools Holiday Finder is used to statistically inspect CUBE surfaces for compliance with bathymetric surface node density requirements.

Automated and visual methods are used to inspect surface coverage: ArcGIS tools are used to automatically identify coverage deficiencies; surfaces are inspected against brightly colored backgrounds for visible gaps in coverage.

CUBE statistical surfaces that show gridded node density are used to visually assess surfaces for compliance with bathymetric surface node density requirements.

D.2.2 Contact Selection Methodology

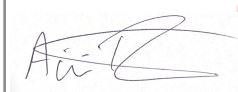
Contacts are selected in accordance with HSSD 2020.

Visual inspection of all SSS data is conducted in CARIS SIPS by multiple scanners (initially processor, check scanner and/or sheet manager).

E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were adhered to during these projects in accordance with the Hydrographic Surveys Specifications and Deliverables (2017 ed) and the Field Procedures Manual for Hydrographic Surveying (2014 ed).

I acknowledge that all of the information contained in this report is complete and accurate to the best of my knowledge.

Approver Name	Approver Title	Date	Signature
CDR Briana W. Hillstrom	Commanding Officer	10/29/2020	 Digitally signed by HILLSTROM.BRIANA.WELTON.1267667531 Date: 2020.10.29 14:08:07 -04'00'
LTJG Airlie Pickett	Field Operations Officer	10/29/2020	 Digitally signed by PICKETT.AIRLIE.GRACE.1539170089 Date: 2020.10.30 09:21:02 -04'00'
Douglas Wood	Chief Hydrographic Survey Technician	10/29/2020	WOOD.DOUGLAS.ALAN.1282580698 Digitally signed by WOOD.DOUGLAS.ALAN.1282580698 Date: 2020.10.30 15:06:01 -04'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	OPR-D304-TJ-20_DAPR_Appendices.pdf
Sound Speed Sensor Calibration	OPR-D304-TJ-20_DAPR_Appendices.pdf
Vessel Offset	OPR-D304-TJ-20_DAPR_Appendices.pdf
Position and Attitude Sensor Calibration	OPR-D304-TJ-20_DAPR_Appendices.pdf
Echosounder Confidence Check	OPR-D304-TJ-20_DAPR_Appendices.pdf
Echosounder Acceptance Trial Results	OPR-D304-TJ-20_DAPR_Appendices.pdf

Additional Report	***File***
HVF Values	OPR-D304-TJ-20_DAPR_Appendices.pdf
HSRR Documentation	OPR-D304-TJ-20_DAPR_Appendices.pdf