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

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	S-G966-NF-20
Time Frame:	August - September 2020

LOCALITY

State(s):	South Carolina
General Locality:	Blake Plateau, 80 NM Offshore of Port Charleston

2020

CHIEF OF PARTY
Julia Wallace, Physical Scientist

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Date:

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NOAA Ship *Nancy Foster*
Chief of Party: Julia Wallace, Physical Scientist
Year: 2020
Version: 1.0
Publish Date: 2020-09-30

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAA Ship NANCY FOSTER

Vessel Name	NOAA Ship NANCY FOSTER	
Hull Number	R352	
Description	R352 is a steel hulled multipurpose oceanographic research vessel built by McDermott Shipyards in Amelia, Louisiana.	
Dimensions	*LOA*	186.4 ft
	Beam	40 ft
	Max Draft	12.6 ft
Most Recent Full Static Survey	*Date*	2018-04-17
	Performed By	The IMTEC Group, Ltd.
Most Recent Partial Offset Verification	*Date*	2020-08-16
	Method	Patch test

Figure 1: NOAA Ship NANCY FOSTER

Figure 2: NOAA Ship NANCY FOSTER, starboard view

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM2040

The Kongsberg EM2040 MBES is a high resolution multibeam echo sounder system for shallow-water depths. The system is capable of operating at 200, 300, or 400 kHz frequencies, can provide across-track swath width up to 7.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 600 meters.

The standard practice aboard NANCY FOSTER is to operate the EM2040 with a maximum swath width of 130 degrees for the 400kHz mode, while the angular coverage for the 200kHz and 300kHz modes can be operated up to 150 degrees, per HSTB recommendations.

Preferred frequency mode varies from project to project based on the needs of each Chief Scientist. It should be noted that NANCY FOSTER's projects typically operate with a focus on backscatter as the primary product, and multibeam bathymetry as a secondary product. This emphasis affects day-to-day decisions made by the Chief Scientist and survey techs on specific runtime parameters used in Kongsberg Seafloor Information System (SIS) acquisition software in order to optimize backscatter quality.

The EM2040 was not used for S-G966-NF-20.

See the NOAA Ship NANCY FOSTER EM2040 Acceptance Testing Report included in the Appendices for a detailed discussion about the EM2040 system on R352.

Note: All equipment information including component names, serial numbers, and calibraiton dates were taken directly from the records kept aboard the ship.

Manufacturer	Kongsberg				
Model	EM2040				
Inventory	*R352*	*Component*	Processer	Projector	Reciever
		Model Number	EM2040	EM2040	EM2040
		Serial Number	N/A	246	369
		Frequency	N/A	200-400 kHz	200-400 kHz
		Calibration	2019-07-02	2019-07-02	2019-07-02
		Accuracy Check	2020-02-20	2020-02-20	2020-02-20

Figure 3: The EM2040 system mounted on the hull of R352, shown during initial installation in 2018.

A.2.1.2 Kongsberg EM710

The Kongsberg EM710; The Kongsberg EM710 is a high resolution mid-water MBES. It is capable of operating at frequencies ranging from 40kHz-100kHz. Across track swath width is up to 5.5 times water depth. The EM710 is operated with a 120-140 degree swath width dynamic swath mode.

The Kongsberg EM710 MBES is a high resolution mid-water MBES. The system is capable of operating at frequencies ranging from 40kHz-100kHz, and can provide across-track swath width of up to 5.5 times water depth.

The standard practice aboard NANCY FOSTER is to operate the EM710 with a swath width of 120-140 degrees with dynamic swath mode for all frequencies, per HSTB recommendations.

Preferred frequency mode varies from project to project based on the needs of each Chief Scientist. It should be noted that NANCY FOSTER's projects typically operate with a focus on backscatter as the primary product, and multibeam bathymetry as a secondary product. This emphasis affects day-to-day decisions made by the Chief Scientist and survey techs on specific runtime parameters used in Kongsberg Seafloor Information System (SIS) acquisition software in order to optimize backscatter quality.

For S-G966-NF-20, the EM710 MBES was operated at with a full frequency range of 40-100kHz. In SIS, the ping mode was set to Auto, and the beam spacing used was both Equidistant and High Definition Equidistant.

See the NOAA Ship NANCY FOSTER EM710 Acceptance Testing Report included in the Appendices for a detailed discussion about the EM710 system on R352.

Note: All equipment information including component names, serial numbers, and calibration dates were taken directly from the records kept aboard the ship.

Manufacturer	Kongsberg				
Model	EM710				
Inventory	*R352*	*Component*	Processor	Reciever	Projector
		Model Number	MP8300H	EM710	EM710
		Serial Number	240	173	240
		Frequency	N/A	40-100 kHz	40-100 kHz
		Calibration	2019-07-02	2019-07-02	2019-07-02
		Accuracy Check	2020-02-21	2020-02-21	2020-02-21

Figure 4: The EM710 system mounted on the hull of R352, shown during installation in 2015.

A.2.2 Single Beam Echosounders

A.2.2.1 Knudsen 3200

A Knudsen 3200 single beam echosounder is installed on the NANCY FOSTER, however it was not used for project S-G966-NF-20.

<table>
<tr><td>Manufacturer</td><td colspan="3">Knudsen</td></tr>
<tr><td>Model</td><td colspan="3">3200</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">R352</td><td>Component</td><td>N/A</td></tr>
<tr><td>Model Number</td><td>3208</td></tr>
<tr><td>Serial Number</td><td>K2K-07-0832</td></tr>
<tr><td>Frequency</td><td>12kHz/200kHz</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
<tr><td>Accuracy Check</td><td>N/A</td></tr>
</table>

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

A.2.5.1 Kongsberg Maritime EK60

The Kongsberg EK60 is a splitbeam sonar used primarily for fishery acoustics. The EK60 was run concurrently with the EM710.

Manufacturer	Kongsberg Maritime
Model	EK60

Inventory — *R352*

Component	Deck Unit	Transducer	Deck Unit	Transducer	Deck Unit	Transducer
Model Number	102-202588 AA EK62 GPT 38kHz Split 2kW	ES38-B 312-073922	102-202588 AA EK62 GPT 120kHz Split 1kW	ES120-7C 312-204022	102-202588 AA EK62 GPT 200kHz Split 1kW	ES200-7C 312-2000841
Serial Number	832	31002	827	1062	830	414
Frequency	38kHz	38kHz	120kHz	120kHz	200kHz	200kHz
Calibration	2019-07-12	2019-07-12	2019-07-12	2019-07-12	2019-07-12	2019-07-12
Accuracy Check	2019-07-12	2019-07-12	2019-07-12	2019-07-12	2019-07-12	2019-08-14

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 V5

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 NANCY FOSTER 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 02 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.

<table>
<tr><td>Manufacturer</td><td colspan="4">Applanix Corporation</td></tr>
<tr><td>Model</td><td colspan="4">POS MV 320 V5</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R352</td><td>Component</td><td>IMU</td><td>PCS</td></tr>
<tr><td>Model Number</td><td>L200</td><td>MVV5</td></tr>
<tr><td>Serial Number</td><td>5223</td><td>8205</td></tr>
<tr><td>Calibration</td><td>2019-06-20</td><td>N/A</td></tr>
</table>

A.5.1.2 Trimble GPS Antenna

Two Trimble GPS antenna units that work in parity with the POS/MV system. The antenna units on located the flying bridge of R352 oriented fore (primary) and aft (secondary) and are both located on the port side of the vessel.

<table>
<tr><td>Manufacturer</td><td colspan="4">Trimble</td></tr>
<tr><td>Model</td><td colspan="4">GPS Antenna</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R352</td><td>Component</td><td>GPS Antenna</td><td>GPS Antenna</td></tr>
<tr><td>Model Number</td><td>AT1675-540TS-TNCF-000-RG-45-NM-R</td><td>AT1675-540TS-TNCF-000-RG-45-NM-R</td></tr>
<tr><td>Serial Number</td><td>10343</td><td>10345</td></tr>
<tr><td>Calibration</td><td>2016-09-15</td><td>2016-09-15</td></tr>
</table>

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

Additional 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

No moving vessel profilers were utilized for data acquisition.

A.6.2 CTD Profilers

A.6.2.1 Teledyne Oceanscience Underway CTD

The Teledyne Oceanscience Underway CTD is a sensor package used to measure conductivity, temperature and pressure in the water column. The Underway CTD is deployed while underway from R352. The Oceanscience Underway CTD (TM) provides research grade CTD (conductivity, temperature, and depth) profiles while underway at up to 20kts. The unique freefall profiler offers researchers vertical profiles even as the ship is moving away from the deployment location. The innovative deployment winch and re-spooling mechanism allows the probe to be recovered and re-launched time after time without ever needing to stop or slow down. Profiles are gathered quickly, allowing excellent spatial resolution for CTD transects.

<table>
<tr><td>Manufacturer</td><td>Teledyne Oceanscience</td></tr>
<tr><td>Model</td><td>Underway CTD</td></tr>
<tr><td>Inventory</td><td><table>
<tr><td>Component</td><td>Probe</td></tr>
<tr><td>Model Number</td><td>UCTD 10400</td></tr>
<tr><td>Serial Number</td><td>702-0340</td></tr>
<tr><td>Calibration</td><td>2019-09-08</td></tr>
</table></td></tr>
</table>

A.6.2.2 Seabird Scientific SBE 19

Sea-Bird Electronics SBE 19 SeaCAT Conductivity, Temperature, and Depth (CTD) Profiler is used on R352 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. The system is configured for a sampling rate of 0.5 seconds. CTD equipment is deployed manually aboard R352 if the use of the UCTD is not possible.

<table>
<tr><td>Manufacturer</td><td colspan="2">Seabird Scientific</td></tr>
<tr><td>Model</td><td colspan="2">SBE 19</td></tr>
<tr><td rowspan="4">Inventory</td><td>Component</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>19-03</td></tr>
<tr><td>Serial Number</td><td>198671-1448</td></tr>
<tr><td>Calibration</td><td>2019-12-26</td></tr>
</table>

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne Reson Reson SV-70

Reson SV-70 sensors are direct-read sound velocity measurement devices. The SV devices are located at the face of the EM710 and EM2040 transducers on R352 and provide real-time surface sound speed data to the Kongsberg MBES systems onboard the vessel. The SV 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.

<table>
<tr><td>Manufacturer</td><td colspan="4">Teledyne Reson</td></tr>
<tr><td>Model</td><td colspan="4">Reson SV-70</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R352</td><td>Component</td><td>SSP</td><td>SSP</td></tr>
<tr><td>Model Number</td><td>70</td><td>70</td></tr>
<tr><td>Serial Number</td><td>218088</td><td>218089</td></tr>
<tr><td>Calibration</td><td>2019-04-04</td><td>2019-04-04</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*
Kongsberg	Seafloor Information System (SIS)	4.3.2	Acquisition
Teledyne Oceanscience	uCast	1.2	Sound Speed Cast Import
Teledyne Caris	HIPS and SIPS	10.4	Processing
NOAA	Pydro XL	19	Processing
HYPACK - A Xylem Brand	HYPACK/HYSWEEP	2020	Navigation and Acquisition Planning
Applanix Corporation	POSView	10.3	Acquisition
Applanix Corporation	POSPac MMS	8.4	Processing
QPS, Inc	Fledermaus GeoCoder Toolbox - FMGT	7.9.5	Processing

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

Vessel offset correctors are the values used to describe the location of all hydrographic sensors in relation to a defined reference point. These values are needed to compute sensor lever arms required to correct for vessel orientation and ultimately produce the final geographic position for every sounding collected.

All offsets for R352 are derived from full surveys performed by Kongsberg USA-contracted personnel (The IMTEC Group) and have been verified by the Hydrographic Systems and Technology Branch (HSTB) personnel. Copies of these reports can be found in the appendices of this document. All offsets are tracked and updated as needed. Offset values are known in the vessel reference frame, the IMU reference frame, the Kongsberg EM710 reference frame, and the Kongsberg EM2040 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 Applanix 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 data during the SVP or Merge processing steps in CARIS HIPS.

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.

B.1.1.1 Vessel Offset Correctors

Vessel	R352			
Echosounder	Kongsberg EM710			
Date	2018-06-06			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.815 meters	0.020 meters
		y	0.619 meters	0.020 meters
		z	1.458 meters	0.020 meters
		x2	1.918 meters	0.020 meters
		y2	-0.587 meters	0.020 meters
		z2	1.472 meters	0.020 meters
	Nav to Transducer	*x*	-6.553 meters	0.020 meters
		y	5.273 meters	0.020 meters
		z	-17.649 meters	0.020 meters
		x2	-6.656 meters	0.020 meters
		y2	6.478 meters	0.020 meters
		z2	-17.662 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	R352			
Echosounder	Kongsberg EM 2040			
Date	2018-06-06			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.776 meters	0.020 meters
		y	-3.041 meters	0.020 meters
		z	1.188 meters	0.020 meters
		x2	0.472 meters	0.020 meters
		y2	-3.142 meters	0.020 meters
		z2	1.173 meters	0.020 meters
	Nav to Transducer	*x*	8.932 meters	0.020 meters
		y	-5.516 meters	0.020 meters
		z	-17.378 meters	0.020 meters
		x2	9.033 meters	0.020 meters
		y2	-5.212 meters	0.020 meters
		z2	-17.363 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

Not applicable, no towfish data were acquired for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

As required based on specific project needs, Static Draft measurements on R352 are taken prior to the vessel departing from the pier. These measurements are performed utilizing a metal weight on a string and measured from the "PROJ" (Project) draft marks on either side of the vessel. EM2040 and /or EM710 multibeam data is logged concurrently.

B.2.1.1 Static Draft Correctors

Vessel		R352
Date		2018-06-06
Loading		0.030 meters
Static Draft	*Measurement*	-1.961 meters
	Uncertainty	0.100 meters

B.2.2 Dynamic Draft

During the Sonar Acceptance Testing (SAT) of the EM2040 MBES system in 2018, the dynamic draft results were determined from a post processed SBET solution using Pydro Explorer's AutoQC tool and results were comparable with past dynamic draft tests. More information on this test can be found in the EM2040 SAT report in the appendices of this document.

B.2.2.1 Dynamic Draft Correctors

Vessel	R352	
Date	2018-06-06	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*
	0.00	0.00
	0.97	0.05
	1.94	0.08
	2.92	0.10
	3.89	0.11
	4.86	0.11
	5.83	0.11
	6.80	0.12
	7.78	0.13
	8.75	0.16
	9.72	0.20
	10.69	0.26
	11.66	0.35
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.03	0.03

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

The Hydrographic Systems and Technology Branch (HSTB) performed Sonar Acceptance Tests (SAT) on the NANCY FOSTER's EM710 and EM2040 MBES systems from 9/9/2015-9/13/2015 and 6/25/2018-6/29/2018 respectively. The reports from these tests can be found in the appendices attached to this document.

Patch tests are performed at least once per season by personnel from Somar Hydro, a contracting company, and are conducted by the field unit and visiting scientists as needed when determined by the Chief Scientist or Survey Technicians. A patch test was performed during Operational Readiness Training, approx. one week before the beginning of S-G966-NF-20. The procedures for this test followed Section 1.5.5.1 of the 2014 Field Procedures Manual (FPM).
All available calibration reports can be found in the Appendix Folder.

** Values below are derived from the Caris HVF file. Alignment correctors are applied directly in the SIS data acquisition software. Please see alignment correctors and attitude timing (latency) correctors applied in the SIS software for the EM2040 and EM710 systems in the Appendix to this report.

B.3.1.1 System Alignment Correctors

Vessel	R352
Echosounder	Kongberg EM2040
Date	2020-08-11

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.003 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	0.000 degrees	0.020 degrees
Roll	0.000 degrees	0.020 degrees
Yaw	0.000 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

Date	2020-08-11

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.003 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	0.000 degrees	0.020 degrees
Roll	0.000 degrees	0.020 degrees
Yaw	0.000 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

Vessel	R352
Echosounder	Kongsberg EM710
Date	2020-08-11

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.003 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	0.000 degrees	0.020 degrees
Roll	0.000 degrees	0.020 degrees
Yaw	0.000 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

Date	2019-08-17

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.003 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	0.000 degrees	0.020 degrees
Roll	0.000 degrees	0.020 degrees
Yaw	0.000 degrees	0.020 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

All multibeam data on NANCY FOSTER is logged using Kongsberg Seafloor Information System (SIS) in the .all file format.

During acquisition aboard NANCY FOSTER, the survey tech:

- 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 backscatter output for indication of interference or blowouts

- 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

- Acquires and processes SVP casts using the Underway CTD every four hours, or less.

Data Processing Methods and Procedures

MBES is processed using Caris HIPS and the Pydro Charlene.

R352 workflow:
Caris HIPS is used to conduct the following basic processing steps for R352:
1. Conversion: Kongsberg ALL (.all) MBES data is converted into the Caris project structure.
2. Load Delayed Heave: TrueHeave data from Applanix POS MV raw logged data is applied to all MBES sounding.
3. Sound Velocity Correct: MBES data is sound velocity corrected using the the Caris method.
4. Compute GPS Tide: GPS tides are computed using real-time ellipsoid height logged in the Kongsberg .ALL files and a VDatum separation model.
5. Merge: MBES data is merged to apply appropriate correctors.

6. Compute Total Propagated Uncertainty (TPU): Uncertainty is computed based on parameters discussed elsewhere in this report.
7. Create Surface: Combined Uncertainty and Bathymetric Estimator (CUBE) bathymetric surfaces are created in accordance with relevant project and OCS survey specifications.

R352 workflow notes:
The procedure outlined above reflects the general workflow use on the ship to process MBES data. An additional step may be added to the workflow for the application of Smooth Best Estimate Trajectory (SBET) files. SBETs are loaded as Auxiliary data in cases where SBET files are used to provide improved ellipsoid height positioning; this processing step occurs after loading Delayed Heave and before Sound Velocity Correcting the data.

Charlene:
Charlene is a Pydro utility that automates the processing workflows described above. The utility is essentially a ‘software wrapper’ that provides a single user interface that can be used to initiate standardized processing workflows. Charlene utilizes Caris and Applanix software Application Programing Interface utilities to initiate a given processing workflow.

The Charlene processing workflow was used aboard NANCY FOSTER for S-G966-NF-20.

MBES data are cleaned regularly in Caris HIPS Subset Editor. Directed Cleaning is employed utilizng QC Tool's Flier Finder (Pydro), to locate potential fliers and direct cleaning to those areas. Visual checks of the surface also lead to spot cleaning, and overall surface cleaning is done if time permits. Regular checks for holidays are employed throughout acquistion. Potential features are identified in the MBES data and are invesigated and developed in accordance with the Project Instructions and the HSSD. A "button-up" plan is created for feature developments and filling holidays if necessary.

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

CUBE gridded surfaces are generated in Caris HIPS following initial bathymetric data processing. CUBE and Variable Resolution (VR) parameter files provided by HSD Operations are used to ensure that gridding parameters and surface computation algorithms comply with the HSSD requirements. Single resolution CUBE surfaces are used for daily quality control and directed editing purposes. Variable resolution grids were created for final products using the Calder-Rice Density method.

Gridded bathymetric surfaces that comply with Project Instruction and HSSD requirements are generated following the completion of on-site acquisition operations and are used for post-acquisition survey processing.

C.1.4.2 Depth Derivation

The surface filtering function in Caris HIPS is not generally used, and it's necessity evaluated on a case-by-case basis as determined by the Chief Scientist and Survey Technicians. Refer to the Descriptive Report for more information.

C.1.4.3 Surface Computation Algorithm

MBES data are gridded using Single Resolution or Variable Resolution CUBE algorithms; these algorithms are implemented in the Caris HIPS surface creation tools used to create gridded bathymetric surfaces. Resolution is dictated by the Project Instructions and section 5.2.2 of the HSSD. HSD gridding parameter files are used to ensure that gridding parameters and surface computation algorithms comply with the requirements in the HSSD and relevant Hydrographic Technical Directives (HTDs).

C.2 Imagery

C.2.1 Multibeam Backscatter Data

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

Backscatter data on NANCY FOSTER are logged in the Kongsberg ALL (.all) file format using Kongsberg SIS software.

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

Backscatter data are processed using the FM Geocoder (FMGT) module of the QPS Fledermaus software package in accordance with OCS standard data processing methods.

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

Data Acquisition Methods and Procedures

NANCY FOSTER uses the raw POS files produced during acquisition that are then postprocessed using POSPac MMS software to produce a trajectory solution in the NAD83 reference frame and an associated uncertainty file containing the realtime uncertainty estimates of the position and attitude data.

NANCY FOSTER does not normally install GNSS reference stations or temporary tide stations for operations on the East Coast. Data from permanently installed GNSS reference stations and/or tide stations (typically maintained by NGS and CO-OPS, respectively) may be used in certain workflows (described below)

Data Processing Methods and Procedures

NANCY FOSTER reduces all data to chart datum via Ellipsoidally Referenced Survey (ERS) workflows for all surveys when possible. The following describes several potential methods of reducing data to chart datum. The Post-processed Precise Point Positioning (5P) and RTX methods were used along with GPS Tide correction for S-G966-NF-20.

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 workflows 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 NANCY FOSTER 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. Vertical control requirements are satisfied through the use of one or more of the following methods.

NANCY FOSTER uses the Fugro Marinestar satellite based corrector service to provide real-time correction to the horizontal position and ellipsoid height for all data acquisition and initial processing. The corrector signal is received on the L1 channel of the POS MV primary GPS antenna. Marinestar correctors are used in the real-time POS MV trajectory solution and are logged in POS MV raw data files. Ellipsoid height values derived from the Marinestar corrected POS MV real-time trajectory solution are logged in all Kongsberg MBES data. The ellipsoid height data present in the Kongsberg MBES files are normally used for all ‘GPS Tides’ computations in Caris HIPS. In the event of issues with the real-time solution, the POS files produced during acquisition can be processed through the POSPac MMS software to produce an SBET in the WGS84 reference frame and an RMS file containing the realtime uncertainty estimates of the position and attitude data. Real-time corrected ellipsoid height is recorded directly in Kongsberg MBES data logged through the Kongsberg SIS program on NANCY FOSTER and is used when processing ship MBES data in Caris HIPS.

Post-processed Precise Point Positioning (5P):
Raw GNSS-INS observables and Marinestar corrector data 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. Raw data can also be post-processed using the 'Create SBET' tool embedded within Charlene.

RTX:
Trimble RTX is a Precise Point Positioning technology similar to the G2 Fugro Marinestar service. The positioning algorithms used by Trimble RTX result in positioning solutions that generally achieve vertical positioning accuracies better than 6 cm (95% real-time and post-processed accuracy). RTX solutions are only available through post-processing in POSPac MMS software as utilized by NOAA and for marine applications. NANCY FOSTER does not currently have regular access to an RTX subscription. The information presented above is noted for reference purposes only.

Non-ERS vertical control approaches:
Two ‘legacy’ workflows could potentially be used to reduce data to chart datums in the event that ERS specifications cannot be achieved. The following workflows are briefly described for reference purposes only.

Discrete Zoned Tides:
This method utilizes one or more National Water Level Observation Network (NWLON) water level gauges and a discrete zoned tidal modal to determine vertical control correctors to be applied to soundings at a given location and time. Co-range and co-phase measurements from the NWLON stations are used to break the project area into zones, each of which has a distinct time-of-tide and range-of-tide corrector. CO-OPS provides the field unit with a Caris compatible file which takes observed water levels from surrounding gauges, computes the time and range correctors for each zone, and uses the zoned data to reduce bathymetric soundings to MLLW. NANCY FOSTER does not install tertiary gauges in support of tidal modeling. After completion of a survey area, CO-OPS verifies all zoning and water level data.

TCARI Tides:
Tidal Constituent and Residual Interpretor (TCARI) is an alternative to discrete zoning. A TCARI grid is a triangulated network that uses two or more water level gauges to create a weighted network across the survey area. Each point on the grid has a discrete tidal interpolation that is based on the horizontal nearness of a water level gauge, the harmonic constants of the area, and the residual water levels. Bathymetric data are then reduced to MLLW using the TCARI tool in Pydro. Like zoned tides, CO-OPS verifies TCARI grids and observed water levels at the conclusion of each survey.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Raw positioning data from the POS MV v5 is 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 Mobile Mapping Suite (MMS) software suite. Utilizing the "Create SBET" automation tool in Charlene (Pydro), POSPac MMS is used to create an RTX SBET in the NAD83 reference frame, and an RMS file containing the realtime uncertainty estimates of the position and attitude data. These files are then applied to the MBES data in post-processing, typically as a part of the Charlene data processing workflow.

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

R352 uses an Oceanscience Underway CTD to acquire sound speed profiles. Profiles aboard the ship are generally acquired at 2-4 hour intervals. Casts are taken at least once every four hours during continuous acquisition. 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. Surface sound speed values measured at the sonar head are monitored for indications of these shifts.

The Underway CTD (UCTD) is a manually operated winch system with which the operator deploys a towfish containing a CTD sensor. The fish is released from the stern of the vessel while underway. The towfish descends at the rate of freefall when deployed and free fall is stopped manually by the operator based on a time calculation for the depth of the cast. The winch is then set to retrieve the sensor and once aboard, it is stowed and communications established via bluetooth for profile download.

Data Processing Methods and Procedures

uCast is a software developed by Oceanscience and is used to download the cast data to an ascii file. Pydro Sound Speed Manager is used to process all sound speed data on NANCY FOSTER. Sound Speed Manager uploads the ascii file and processes the sound speed data. Sound speed profiles are visually checked for obviously erroneous data and compared against available historical data. Sound speed cast data is provided to the Kongsberg SIS acquisition program using a data distribution function built into the Sound Speed Manager software. Processed casts are then exported to a '.svp' file for later application to the MBES data in Caris HIPS. Additionally, sound velocity profiles are exported to a '.nc' file for archival at NCEI.

Due to the manual operation of the UCTD system, the probe does not often reach within 30m of the seafloor. In order to account for potential sound speed variability in deeper water, the sound speed profiles are often extended using Pydro Sound Speed Manager. When possible, a 'reference cast' is used to extend the profiles. The reference cast is a sampling of one of the deepest areas in the survey area and is retaken once per day. In Sound Speed Manager, a cast is extended past its maximum depth based on the reference cast, using the Extend Profile tool. See Sound Speed Manager documentation for further explanation of Extend Profile. When taking a reference cast is not possible, often in waters deeper than 500m, World Ocean Atlas is used to set the reference information. This option is selected in the Settings tab in Sound Speed Manager. See Sound Speed Manager documentation for more information.

All sound velocity profiles are exported from Sound Speed Manager into a concatoncated file, which is applied to the MBES data in post-processing using a "Nearest in Distance within 4 hours" application method.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

A Kongsberg SVP 70 probe is used to measure the speed of sound at the tranducer head of each MBES system on board.

Sound speed values are applied in real-time to all MBES systems to provide refraction corrections to flatfaced transducers. The accuracy of each surface sound speed device is checked against the closest CTD data point after every CTD cast and the ship's Thermosalinograph (TSG).

Data Processing Methods and Procedures

Surface sound speed data are logged directly into both Kongsberg raw data files and raw/processed sound speed files and are monitored in SIS during acquisition. These values are to guide beam steering and gain adjustments as necessary and determined by the Chief Scientist and Survey Technicians.

Surface sound speed data are 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 depend on the method of correction: static values specified in the Project Instructions are used for Zoned Tides or ERS workflows.

Ellipsoid height uncertainty values for ellipsoid measurements derived from the Marinstar service are derived from both manufacturer specifications and empirical observation. Static values are used to account for known discrepancies with the magnitude of the position uncertainty values reported by the POS MV system when utilizing Marinestar correctors.

Ellipsoid height uncertainty values for ellipsoid measurements derived from the 5P workflow are applied as real-time values from Applanix RMS files.

The Kongsberg MBES 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		R352
Motion Sensor	*Gyro*	0.10 degrees
	Heave	5.00% 0.02 meters
	Roll	0.02 degrees
	Pitch	0.02 degrees
Navigation Sensor		2.00 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
R352	Some real-time uncertainty values are incorporated into the depth estimates of NANCY FOSTER surveys by way of post-processing. Real-time uncertainties from the Kongsberg EM2040 and Kongsberg EM710 are recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.

C.7 Shoreline and Feature Data

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

The following workflow is used to develop and verify features:

- Potentially significant features are initially identified and inspected in Caris HIPS.

- A development area polygon or point feature is exported from Caris HIPS; a line plan is created using Hypack or HIPS.

- Object Detection level MBES data are collected over all MBES contacts 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 resultant 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. 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, the least depths over navigationally significant features are flagged as 'designated soundings', then imported into Caris HIPS. Inside HIPS, each significant contact is given an S-57 attribution, per the HSSD, 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 guide directed cleaning of potential 'fliers' in the bathymetric surface data in subset editor. The surfaces and subset editor views were also used to demonstrate coverage and to check for errors due to tides, sound speed, attitude and timing.

D.1.2 Designated Sounding Selection

Designated soundings were selected as outlined in section 5.2.1.2.3 of the HSSD.

D.1.3 Holiday Identification

Holidays are identified with the Holiday Finder function in Pydro QC Tools. All surfaces are also visually inspected for potential holidays. Holidays were identified as outlined in section 5.2.2.3 of the HSSD based on the assigned coverage type.

D.1.4 Uncertainty Assessment

QC Tools included as part of Pydro Explorer contains the tool “Grid QA” which largely automates the computation of grid statistics to ensure compliance to uncertainty and density requirements. The Depth, Uncertainty, Density (if available), and a computed Total Vertical Uncertainty (TVU) QC layer (optional) are used to compute particular statistics shown as a series of plots. The TVU QC is either given to the program in the grid input, or calculated on-the-fly. It is determined by a ratio of uncertainty to allowable error per NOAA and IHO specification. Grid QA outputs the following plots:

Data Density plotted as Soundings per node against the Percentage of nodes in each sounding density group.
Uncertainty Standards as Node uncertainty as a fraction of allowable IHO TVU against the Percentage of nodes in each uncertainty group.

These plots once generated are analyzed for compliance with the applicable specifications and may be included in the Descriptive Report as proof of compliance.

ERS tide zoning uncertainty is unique to the separation model in use.

Measured sound speed value error ranges from 0.5 to 4 m/s, dependent on temporal/spatial variability. FPM recommends a value of 4 m/s when 1 cast is taken every 4-hours.

Surface sound speed value is dependent on the manufacturer specifications of the unit utilized to measure surface SV values for refraction corrections to flat-faced transducers. All other error estimates are read from the Hydrographic Vessel File (HVF) and Device Model file. The HVF contains all offsets and system biases for the survey vessel and its systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements.

The HVF specifies which type of sonar system the vessel is using, referencing the appropriate entry from the Device Model file.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Difference surfaces are conducted in accordance with section 5.2.4.2 of the HSSD and as outlined in the DR.

D.1.5.2 Junctions

Junction comparisons are conducted in accordance with section 7.2.2 of the HSSD and as outlined in the DR.

D.1.5.3 Platform to Platform

Platform to platform comparisons are conducted in accordance with HSSD 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.

Automated and visual methods are used to inspect surface coverage: CUBE statistical surfaces that show gridded node density are used to visually assess surfaces for compliance with bathymetric surface node density requirements. Pydro QC Tools is used to statistically inspect CUBE surfaces for compliance with bathymetric surface node density requirements.

D.2.2 Contact Selection Methodology

Contacts are selected in accordance with HSSD.

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 (2020).

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
Julia Wallace	Chief of Party	09/30/2020	

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	Appendix1_WiringDiagramsNote.pdf
Sound Speed Sensor Calibration	Appendix2_SoundSpeedCalibrationReportsNote.pdf
Vessel Offset	Appendix3_Nancy Foster Mar IMTEC Survey 2015-2018-Rev-4.pdf
Position and Attitude Sensor Calibration	Appendix4_PositionAttitutdeSensorCalibrationReportsNote.pdf
Echosounder Confidence Check	N/A
Echosounder Acceptance Trial Results	Nancy Foster EM2040 SAT June2018.pdf NF_EM710_acceptance.pdf

Additional Report	***File***
NANCY FOSTER Kongsberg EM2040 SIS Angular Offsets and Sensor Settings	NF_EM2040_AngularOffsets_25Aug2020.JPG NF_EM2040_Settings_25Aug2020.JPG
NANCY FOSTER Kongsberg EM710 SIS Angular Offsets and Sensor Settings	NF_EM710_AngularOffsets_25Aug2020.JPG NF_EM710_Settings_25Aug2020.JPG
NANCY FOSTER Kongsberg EM2040 Caris HVF	R352_EM2040_2020.hvf
NANCY FOSTER Kongsberg EM710 Caris HVF	R352_EM710_2020.hvf