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-M328-FA-22
Time Frame:	November - November 2022

LOCALITY

State(s):	California Oregon
General Locality:	Offshore, OR and Channel Islands, CA

2022

CHIEF OF PARTY
CAPT John "Jay" Lomnicky

LIBRARY & ARCHIVES

Date:

Notes: OPR-M328-FA is a multi-year project spanning 2021 and 2022
DAPR pertaining to EM710 sonars: pages 1 - 53
DAPR pertaining to EM712 sonars: pages 54 - 105

Table of Contents

List of Figures

Data Acquisition and Processing Report

NOAA Ship *Fairweather*
Chief of Party: CAPT John "Jay" Lomnicky
Year: 2022
Version: 1.0
Publish Date: 2022-11-05

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAA Ship Fairweather

Vessel Name	NOAA Ship Fairweather
Hull Number	S220
Description	NOAA S Fairweather (S220) is a 70.4 meter oceanographic research vessel owned and operated by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). It has a welded steel and ice strengthened hull for an ABS classification of #A1, #AMS.
Dimensions	*LOA*: 70.4 meters *Beam*: 12.8 meters *Max Draft*: 4.8 meters
Most Recent Full Static Survey	*Date*: 2022-01-01 *Performed By*: IMTEC Group, Ltd.

Figure 1: NOAA Ship Fairweather S220

A.1.2 FA 2805

Vessel Name	FA 2805	
Hull Number	2805	
Description	FA 2805 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 2: FA 2805

A.1.3 FA 2806

Vessel Name	FA 2806
Hull Number	2806
Description	FA 2806 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.
Dimensions	*LOA*: 8.6 meters *Beam*: 3.5 meters *Max Draft*: 1.1 meters

Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 3: FA 2806

A.1.4 FA 2807

Vessel Name	FA 2807
Hull Number	2807
Description	FA 2807 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.

Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 4: FA 2807

A.1.5 FA 2808

Vessel Name	FA 2808
Hull Number	2808
Description	FA 2808 is a Jenson "Type 1" aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.
Dimensions	*LOA*: 8.6 meters *Beam*: 3.5 meters *Max Draft*: 1.1 meters
Most Recent Full Static Survey	*Date*: 2021-01-27 *Performed By*: Reality Documentation Solutions

Figure 5: FA 2808

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM 712

S220 has a hull-mounted Kongsberg EM 712 multibeam echosounder (MBES), which operates at sonar frequencies in the 40 to 100 kHz range. The maximum utilized across-track swath coverage is 140° with a published maximum depth of > 3600 meters. The along track beam width configuration is 0.25° with a receive beam width of 0.5°. The system forms 1600 soundings per swath with equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range of the EM 710 is 10 to 2500 meters.

Manufacturer	Kongsberg			
Model	EM 712			
Inventory	*S220*	*Component*	Transmit Array	Receive Array
		Model Number	EM 712	EM 712
		Serial Number	232	232
		Frequency	40-100 kHz	40-100 kHz
		Calibration	2021-05-10	2021-05-10
		Accuracy Check	2021-05-10	2021-05-10

Figure 6: EM 712 gondola during transducer installation

A.2.1.2 Kongsberg EM 2040

HSLs 2805, 2806, 2807, and 2808 are each equipped with a Kongsberg EM 2040 MBES. The EM 2040 is capable of operating at low frequency (200 kHz), intermediate frequency (300 kHz), and high frequency (400 kHz), with maximum swath coverage of 150°. At the common usage frequency of 300 kHz, the beam width is 1° for both TX and RX. The system forms 256 beams, with dynamic focusing employed in the near field. The system forms 400 soundings per swath with an equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range for the EM 2040 is 0.5 to 600 meters.

Manufacturer	Kongsberg			
Model	EM 2040			
Inventory	*2805*	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	255	354
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2806	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	249	351
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2807	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	247	355
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2808	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	251	356
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2021-05-13

Figure 7: EM 2040 Transceiver Array

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 POS MV 320 V5

The POS MV V5 calculates position, heading, attitude, and vertical displacement (heave) of a vessel. It consists of a rack mounted POS Computer System (PCS), a bolted down IMU-200 Inertial Measurement Unit (IMU), and two GNSS antennas corresponding to GNSS receivers in the PCS.

Manufacturer	Applanix POS MV					
Model	320 V5					
Inventory	*S220*	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	L200	Zephyr 2	Zephyr 2
		Serial Number	8194	5226	1440904133	31180200
		Calibration	2022-04-22	2022-04-22	2022-04-22	2022-04-22
	2805	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	L200	GA830	GA830
		Serial Number	8198	5222	21374	21375
		Calibration	2022-04-18	2022-04-18	2022-04-18	2022-04-18
	2806	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	L200	GA830	GA830
		Serial Number	8197	5224	23164	23168
		Calibration	2022-04-12	2022-04-12	2022-04-12	2022-04-12
	2807	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	L200	GA830	GA830
		Serial Number	8195	5225	9968	9962
		Calibration	2022-04-06	2022-04-06	2022-04-06	2022-04-06
	2808	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
		Model Number	320 V5	L200	GA830	GA830
		Serial Number	8196	5227	16724	16727
		Calibration	2022-04-12	2022-04-12	2022-04-12	2022-04-12

Figure 8: POS MV 320 V5 System

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

A.5.4.1 Laset Tech TruPulse 200

The TruPulse laser rangefinders are used to measure the static draft of S220, as well as to take range and bearing measurements to shoreline objects.

<table>
<tr><td>Manufacturer</td><td colspan="2">Laset Tech</td></tr>
<tr><td>Model</td><td colspan="2">TruPulse 200</td></tr>
<tr><td>Inventory</td><td>S220</td><td>
<table>
<tr><td>Component</td><td>Laser Rangefinder</td><td>Laser Rangefinder</td></tr>
<tr><td>Model Number</td><td>TruPulse 200</td><td>TruPulse 200</td></tr>
<tr><td>Serial Number</td><td>LR 041156</td><td>LR 041169</td></tr>
<tr><td>Calibration</td><td>2021-02-08</td><td>2021-05-13</td></tr>
</table>
</td></tr>
</table>

Figure 9: TruPulse 200 Laser Rangefinder

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 MVP 200

The MVP 200 is a self-contained system capable of sampling water column profiles to depths of 200 meters from a vessel moving at up to 12 kts, achieving greater depths at slower speeds. During towed operation, the MVP 200 can be controlled by computer without the requirement for personnel on deck. The system consists of a single sensor free fall fish, an integrated winch and hydraulic power unit, a towing boom, and a remotely located computer controller with a user interface. Fairweather's MVP fish is equipped with an AML Oceanographic Micro-CTD sensor capable of acquiring conductivity, temperature, and depth (CTD) profiles to determine the speed of sound and absorption in the water column, primarily to correct bathymetry data acquired with the EM 710 MBES.

<table>
<tr><td>Manufacturer</td><td colspan="3">AML Oceanographic</td></tr>
<tr><td>Model</td><td colspan="3">MVP 200</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S220</td><td>Component</td><td>CTD Sensor</td></tr>
<tr><td>Model Number</td><td>Micro-CTD</td></tr>
<tr><td>Serial Number</td><td>8817</td></tr>
<tr><td>Calibration</td><td>2021-03-14</td></tr>
</table>

Figure 10: MVP 200 System

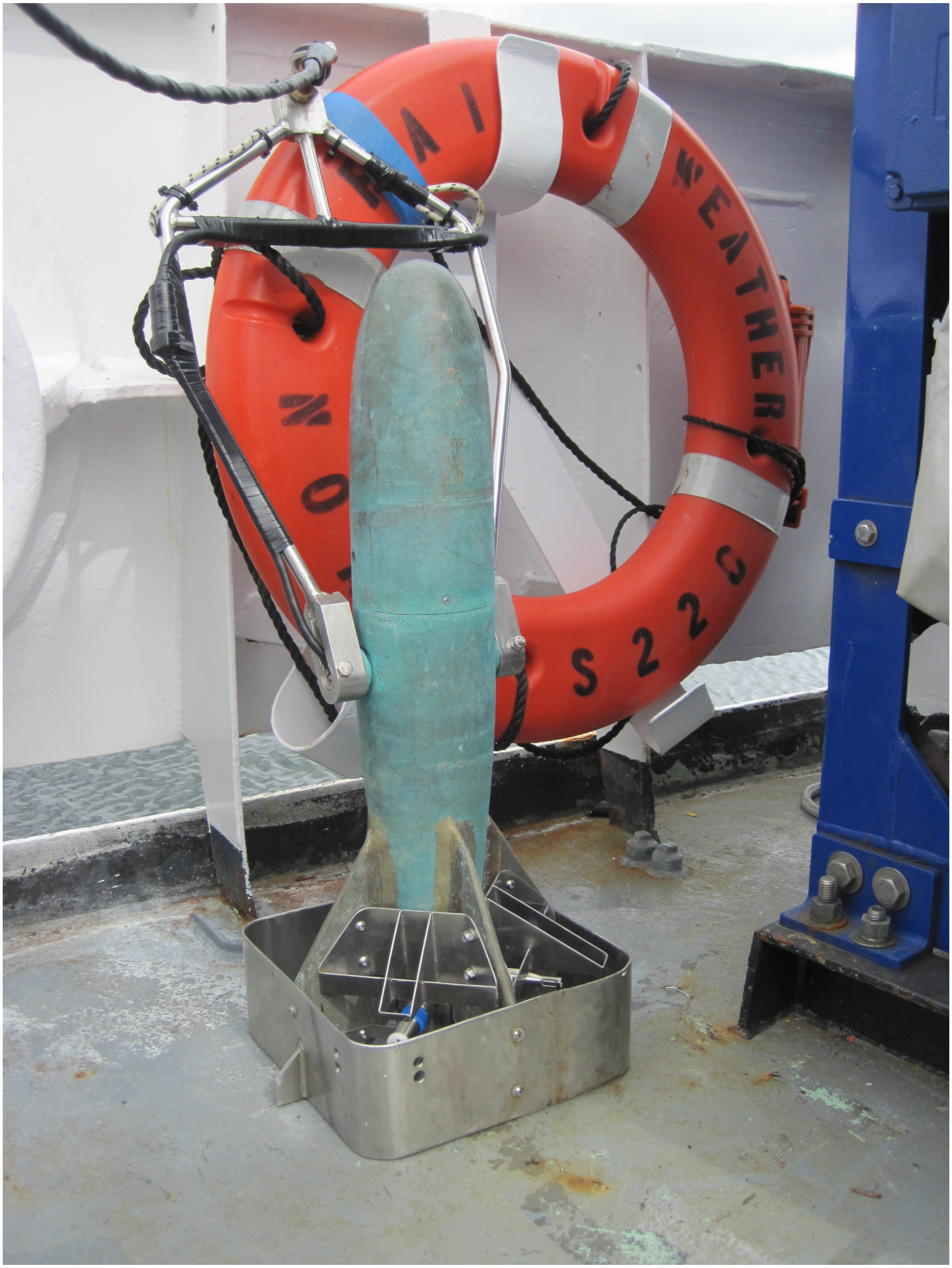

Figure 11: Single Sensor Free Fall Fish

A.6.2 CTD Profilers

A.6.2.1 Sea-Bird Electronics SBE CTD

Fairweather utilizes SBE 19plusV2 SeaCAT sound speed profilers to acquire conductivity, temperature, and depth (CTD) data throughout the water column. The SBE 19plusV2 have pressure sensors rated to 600 m. All SeaCAT sound speed profilers were calibrated by the manufacturer during the 2020 -2021 winter repair period. The survey department performs quality checks and comparison casts on any instruments on a routine basis.

<table>
<tr><td>Manufacturer</td><td>Sea-Bird Electronics</td></tr>
<tr><td>Model</td><td>SBE CTD</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td>Component</td><td>CTD</td><td>CTD</td><td>CTD</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>SBE 19plusV2</td><td>SBE 19plusV2</td><td>SBE 19plusV2</td><td>SBE 19plusV2</td></tr>
<tr><td>Serial Number</td><td>7634</td><td>6121</td><td>6122</td><td>7370</td></tr>
<tr><td>Calibration</td><td>2022-06-13</td><td>2022-06-13</td><td>2022-06-13</td><td>2022-06-13</td></tr>
</table>
</td></tr>
</table>

Figure 12: SBE 19plusV2

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne RESON SVP-71

The SVP-71 is a direct-reading sound speed probe with a 125 mm sound transmission path. The unit's housing composition is hard, anodized, sea water resistant aluminum. This sensor is mounted in proximity to the multibeam transceiver on each HSL, providing real-time surface sound speed values for refraction corrections.

Manufacturer	Teledyne RESON		
Model	SVP-71		
Inventory	*2805*	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	3511355
		Calibration	2019-05-28
	2806	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	2008038
		Calibration	2019-05-28
	2807	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	1213046
		Calibration	2019-05-28
	2808	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	1713034
		Calibration	2019-05-28

A.6.3.2 Teledyne RESON SVP-70

The SVP-70 is a direct-reading sound speed probe with a 125 mm sound transmission path. The unit's housing is composed of robust titanium, which reduces marine growth on these continually submerged sensors. S220 has two sensors in proximity to the ship's multibeam transducer.

Manufacturer	Teledyne RESON			
Model	SVP-70			
Inventory	*S220*	*Component*	Surface Sound Speed Sensor	Surface Sound Speed Sensor
		Model Number	SVP-70	SVP-70
		Serial Number	0614171	0614172
		Calibration	2019-03-29	2021-05-14

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*
Teledyne CARIS	HIPS and SIPS	11.4.6	Processing
Teledyne CARIS	BASE Editor	5.5.25	Processing
Applanix	MV POSView	10.2	Acquisition
Applanix	POSPac	8.7	Processing
Quality Positioning Services BV (QPS)	Fledermaus Geocoder Toolbox (FMGT)	7.10.1	Processing
Kongsberg Maritime AS	Seafloor Infomation System (SIS)	5.9	Acquisition
NOAA Hydrographic Systems and Technology Branch	Pydro Explorer	19.4	Acquisition and Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Kahlisco Mud Snapper

The Kahlsico Mud Snapper is a hand held bottom sampler that is used aboard all Fairweather launches.

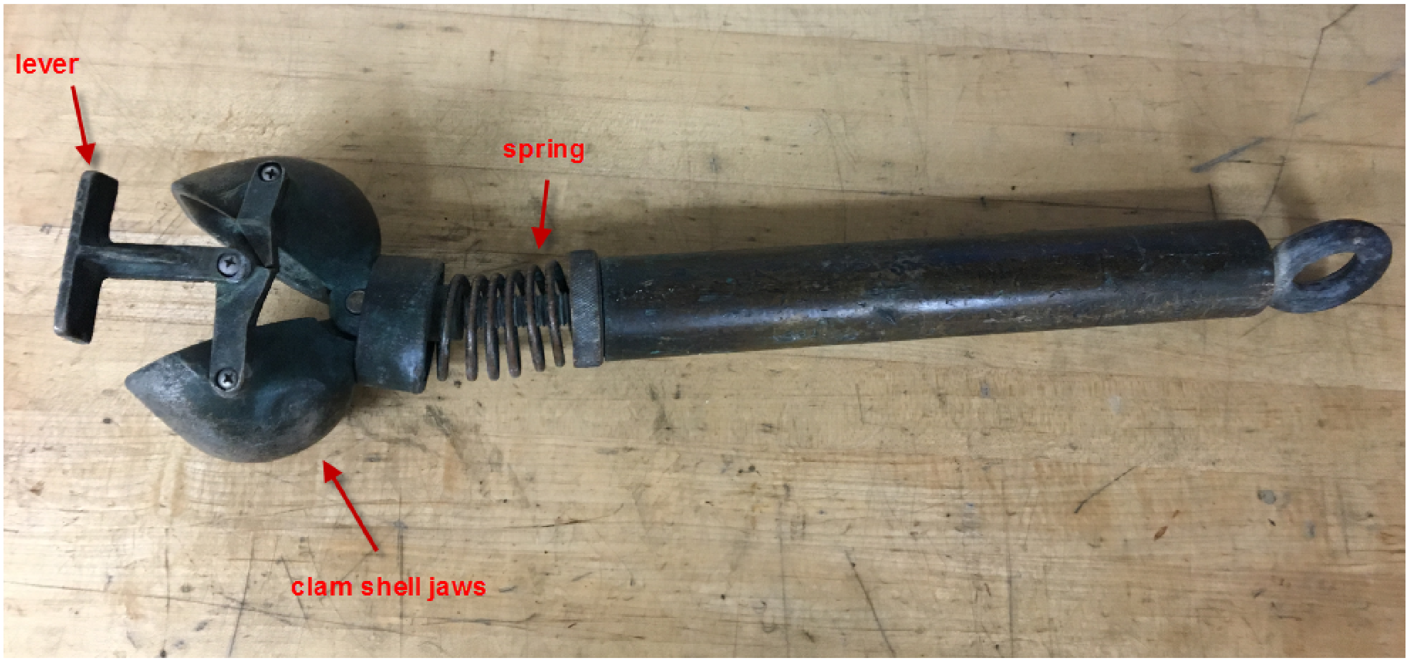

Figure 13: Mud Snapper style grab sampler used about NOAA Ship Fairweather launches.

A.8.1.2 Kahlsico Torpedo Sampler

The Kahlsico Torpedo Sampler is a hand held bottom sampler that is used aboard all Fairweather launches.

Figure 14: Torpedo style grab sampler used about NOAA Ship Fairweather launches.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

B.1.1 Vessel Offsets
The reference point for all positioning, attitude, and sonar systems maintained by Fairweather is co-located at the phase center of the sonar transmitter and rotated to the face of the transducer for the EM 2040 installations on the HSLs. A single reference point simplifies downstream processing and reduces potential errors from incorrect entered offset values in the CARIS HIPS Vessel File (HVF). This was achieved for position and attitude by entering the surveyed translational and rotational offsets of the IMU and GNSS

antennae for each platform into the respective POS configuration. Thus the position and attitude reported by the POS, including heave and delayed heave, are valid at the transmit array. Furthermore, this reference point is the center of rotation in POS for the purposes of applying the heave filter, as the reference to center of rotation field is zero.

Rotational and translational offsets for the HSL EM 2040 systems, offsets were derived from a combination of values from the 2010 NGS survey of permanent control benchmark points on the launch hull, engineering drawings of the sonar mount, and directly measured offsets from control points to equipment interfaces. Due to the relatively short baselines between HSL systems, minor differences resulting from survey methods or CAD drawing discrepancies are not expected to introduce significant error.

Transducer and navigation offsets and alignments were entered in SIS according to the EM 2040 transmitter reference frame. The translational and angular offsets of the receiver array (labeled “RX Transducer”) relative to the transmit array were entered into SIS. The location of the reference point at the transmit array allows the translational and angular offsets from the transmit array (TX Transducer) to the reference frame to be zero. Since the reference point of the POS was configured to be located at and aligned with the transmit array centered frame, the offsets for the position and attitude data from the POS are also zero in SIS. With this approach, any residual misalignment between the EM 2040 and the IMU discovered in a patch test (see Section B.3.1) was added to the IMU alignment with respect to the reference frame in the POS configuration, maintaining the transmit array as aligned with the reference frame.

Entries in the CARIS HVF account for the offset between the transmit and receive arrays for the EM 2040 systems, entered under the SVP 2 section so processing of raw range-angle data is correct after sound speed profile corrections are applied. All other vessel offset values have been set to zero and apply to “No” to avoid double-correction. Offsets to the IMU and primary GNSS antenna are also entered under the TPU section, but this is only used for estimates of uncertainty and not positioning of soundings.

B.1.1.1 Vessel Offset Correctors

<table>
<tr><td>Vessel</td><td colspan="4">FA 2805</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg EM 2040 300 kHz Mode</td></tr>
<tr><td>Date</td><td colspan="4">2022-04-20</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.201 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.159 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.499 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.102 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.063 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.484 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.904 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.949 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.694 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.601 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.853 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.679 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="4">FA 2806</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg EM 2040 300 kHz Mode</td></tr>
<tr><td>Date</td><td colspan="4">2022-04-20</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.196 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.146 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.503 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.106 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.048 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.491 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.911 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.979 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.694 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.609 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.880 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.682 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="4">FA 2807</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg EM 2040 300 kHz Mode</td></tr>
<tr><td>Date</td><td colspan="4">2022-04-20</td></tr>
<tr><td rowspan="17">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.198 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.141 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.506 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.098 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.034 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.515 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.907 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.950 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.691 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.611 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.843 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.700 meters</td><td>N/A</td></tr>
<tr><td rowspan="3">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

<table>
<tr><td>Vessel</td><td colspan="4">FA 2808</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg EM 2040 300 kHz Mode</td></tr>
<tr><td>Date</td><td colspan="4">2022-04-20</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.199 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.148 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>0.498 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>-0.098 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.048 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.483 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.926 meters</td><td>0.006 meters</td></tr>
<tr><td>y</td><td>0.973 meters</td><td>0.006 meters</td></tr>
<tr><td>z</td><td>3.685 meters</td><td>0.006 meters</td></tr>
<tr><td>x2</td><td>0.628 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.873 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>3.671 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.000 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.000 degrees</td><td></td></tr>
</table>

Vessel	S220			
Echosounder	Kongsberg EM 710			
Date	2021-03-02			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.728 meters	0.002 meters
		y	8.427 meters	0.002 meters
		z	4.646 meters	0.002 meters
		x2	1.839 meters	N/A
		y2	7.204 meters	N/A
		z2	4.644 meters	N/A
	Nav to Transducer	*x*	0.764 meters	0.002 meters
		y	20.218 meters	0.002 meters
		z	17.876 meters	0.002 meters
		x2	0.875 meters	N/A
		y2	18.995 meters	N/A
		z2	17.874 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

No towed arrays were utilized for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

The static drafts (Waterline Height in the HVF) for HSLs are calculated based on steel tape and plumb bob measurements of the distance from benchmarks on the port and starboard quarter of the vessel to the waterline. These measurements were combined with the offset from these benchmarks to the sonar transducer to determine the waterline relative to the reference frame.

Measurements for the HSLs were conducted in March of 2021 in Seattle, WA. Values utilized for the 2021 season were based on an average of waterline values from 2017-2021. No significant stability alterations have occurred in this time period, with the added benefit of mitigating measurement error by using historical averages. The values and calculations for static draft of the HSLs are listed in the respective Waterline Measurement spreadsheets included within this report.

Static draft for S220 was conducted on March of 2021. Static draft for Fairweather is determined by using a laser rangefinder to measure the vertical distance to the water from benchmarks on the port and starboard E-Deck breezeway below the bridge wings. The measurements are translated to the transmitter reference frame using surveyed offsets to the benchmarks. The loading condition of the ship, particularly fuel and launches, has a more significant influence on static draft than just the launches. To compensate for static draft changes, static draft values are measured on S220 after any changes in fuel levels, and at the start of survey operations for each leg throughout the season. These measurements are taken while the vessel is at anchor or hove to.

For both the S220 and HSL sonar systems, static draft corrector values are entered in the Kongsberg SIS Installation Parameters window. In addition, waterline values are entered in the CARIS HVF. For S220, only the HVF is updated with the measurements taken throughout the field season, as this will override the SIS waterline during processing. The waterline value in CARIS will only be used during Sound Speed Correction. The Apply switch is set to “No” to avoid double application of the waterline value during HIPS merge.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
FA 2805	2022-04-20	0.018 meters	-0.622 meters	0.014 meters
FA 2806	2021-03-20	0.018 meters	-0.624 meters	0.011 meters
FA 2807	2022-04-20	0.018 meters	-0.639 meters	0.010 meters
FA 2808	2022-04-20	0.018 meters	-0.631 meters	0.014 meters
S220	2021-03-20	0.116 meters	-4.650 meters	0.128 meters

B.2.2 Dynamic Draft

Dynamic draft data were not acquired in 2022 due to time constraints. The method Fairweather employs calculates the vessel's ellipsoid height change while transiting at different speeds in a straight line. The ellipsoid heights were determined using a Post Processed Kinematic (PPK) trajectory for each vessel through processing the recorded POS MV data with RTX correctors in Applanix POSPac MMS software. A third order polynomial curve was fit to the speed versus ellipsoid height data using a least squares fit through a script implemented in the POSPac AutoQC tool.

Dynamic draft data for the years 2020 and 2021 were analyzed but not found consistent or ultimately suitable for computation of dynamic draft models. Wind and sea state conditions did not allow for satisfactory achievement of the ellipsoidally referenced dynamic draft model (ERDDM) steps coupled with engine speed changes. Time and weather constraints did not allow for repeated attempts of acquiring dynamic draft data.

Since all launches are of essentially identical construction, a historical average for all launches using data from 2016-2019 was used to populate the CARIS HVF in order to reduce uncertainty introduced by wave action noise. Outlier vessel measurements with multiple delta draft values more than two standard deviations from the mean were removed from the average. The standard deviation of the residuals was used to determine the associated uncertainty in the measurement.

B.2.2.1 Dynamic Draft Correctors

Vessel	S220		FA 2805, 2806, 2807,and 2808	
Date	2019-04-11		2019-04-11	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*
	0.00	0.00	0.00	0.00
	1.50	0.01	0.50	0.00
	2.00	0.03	1.00	0.01
	2.50	0.06	1.50	0.03
	3.00	0.08	2.00	0.04
	3.50	0.11	2.50	0.05
	4.00	0.14	3.00	0.06
	4.50	0.17	3.50	0.06
	5.00	0.20	4.00	0.05
	5.50	0.23	4.50	0.03
	6.00	0.25	5.00	0.00
	6.50	0.27	5.50	-0.03
			6.00	-0.08
			6.50	-0.13
			7.00	-0.17
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.03	0.10	0.03	0.03

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Patch test data for FA 2805, 2807, and 2808 were collected in Sausalito, CA, and in offshore San Francisco, CA for S220. Patch lines were along a slope and over a corresponding flat area with two parallel lines; one line was run twice in opposite directions while the parallel line was run once. Pitch and roll offsets utilized the lines run in reciprocal directions in the same location. The pitch calibration focused on the slope portion, and the roll calibration focused on the flat portion of the lines. The yaw offset focused the slope of two offset, parallel lines with the same heading.

Patch test data were converted in both QPS Qimera and CARIS HIPS, with multiple personnel determining patch test values. Qimera data were converted with vessel settings to zero and processed using the auto-calibration tool. Data were converted in CARIS HIPS using an HVF file with heave, pitch, roll, and timing values set to zero. Delayed heave, SBETs, SBET RMS, the most recent dynamic draft, sound speed correctors, and GPS tides via a VDATUM separation model were applied and the data were georeferenced before cleaning via Subset Editor.

Bias values were determined in the following order; pitch, yaw, roll. A minimum of five individual testers determined alignment test biases in CARIS and Qimera. A reviewer then examined these results for outlier elimination, after which the remaining results were averaged. The averaged values were entered as opposite sign rotations into the POS MV angular offsets in “IMU Frame w.r.t. Ref Frame" within the Lever Arms & Mounting Angles setup. The values for roll, pitch, and yaw correctors were entered as X, Y, and Z, respectively. These rotations are therefore applied to all raw orientation data output from the POS.

An additional examination of the correlation between a bathymetric roll artifact and the motion time series is used to solve for timing errors that are difficult to detect in the traditional patch test methodology. From these results, a constant timing delay is applied to all motion data in Kongsberg SIS. A value of 7 milliseconds is used for all HSLs and a value of 14 milliseconds for S220.

The values listed below are those entered into the POS MV, as the alignment values in the HVF are all set to zero.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>FA 2805</td></tr>
<tr><td>Echosounder</td><td>Kongsberg EM 2040</td></tr>
<tr><td>Date</td><td>2022-04-20</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>0.120 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Roll</td><td>-0.010 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Yaw</td><td>-0.430 degrees</td><td>0.120 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

Vessel	FA 2806
Echosounder	Kongsberg EM 2040
Date	2021-04-02

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	2.360 degrees	-0.010 degrees
Roll	0.040 degrees	-0.010 degrees
Yaw	-0.770 degrees	0.120 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	FA 2807
Echosounder	Kongsberg EM 2040
Date	2021-03-16

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.200 degrees	-0.010 degrees
Roll	-0.610 degrees	-0.010 degrees
Yaw	0.260 degrees	0.120 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	FA 2808
Echosounder	Kongsberg EM 2040
Date	2021-03-16
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.400 degrees	-0.010 degrees
Roll	0.040 degrees	-0.010 degrees
Yaw	-0.460 degrees	0.120 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	S220
Echosounder	Kongsberg EM 710
Date	2021-03-19
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.091 degrees	0.040 degrees
Roll	0.086 degrees	0.040 degrees
Yaw	0.178 degrees	0.060 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Acquisition methods employed are determined based on consideration of sonar system specifications, seafloor topography, water depth, and the capabilities of the acquisition platforms. They are also dictated by the coverage method specified in the Project Instructions for a survey area. For the Kongsberg EM 2040, all multibeam data were acquired in the .all format within the SIS (Seafloor Information System) software. Data were monitored in 2D, 3D, and backscatter imagery real-time display windows. A survey template defined the storage location of raw and gridded (survey) data, and the file naming convention for mainscheme (Filename_M.all) and crossline (Filename_X.all) data. During acquisition, the hydrographers often adjusted parameters of the Kongsberg systems to improve data quality. The following are parameters that are commonly adjusted: the port and starboard beam angle, the force depth fields, ping mode, and yaw stabilization. Settings and specialized filters are found in the Runtime Parameters tear off window within SIS.

During launch acquisition, mainscheme MBES lines are generally run parallel to depth contours with appropriate overlap to ensure the data density requirements for the proper finalized CUBE surfaces are met. For discrete item developments, 200 percent coverage is acquired to ensure least-depth determination by multibeam near-nadir beams. For complete coverage surveys, the HYPACK HYSWEEP realtime coverage display is used in lieu of pre-planned line files. HYSWEEP displays the acquired multibeam swath during acquisition and is monitored to ensure overlap and full bottom coverage. For areas where shoreline verification is not conducted before multibeam acquisition and hazards are suspected to exist, extra caution is taken by “half stepping” shoreward when operating near shore. Half stepping is executed by driving along the edge of real time coverage to prevent the survey vessel from working in un-surveyed waters. Survey launch crews in the field survey to the Navigable Area Limit Line (NALL) line as defined by section 1.3.2 of the HSSD.

Seafloor backscatter data were acquired for all lines during the 2021 field season, logged in the .all files.

Navigation and motion data are acquired and monitored in POSView and logged to a POS MV file with a .### extension, starting with .000. Data are logged on a USB flash drive inserted into the PCS and automatically split into 12 MB files. Various position and heading accuracies, as well as satellite constellations, are monitored real-time both in POSView and in Hypack Hysweep to ensure the collection of quality data. It is standard procedure not to log the POS/MV data through UTC midnight on Saturdays. At this time the GPS seconds of the week reset.

Data Processing Methods and Procedures

Following daily acquisition, all data are loaded to an external hard drive connected to the launch acquisition computer. This drive contains a standard file structure created by Charlene, an automated data transfer and batch processing software developed by HSTB and distributed within the PydroXL software suite.

Initial processing is typically completed the same day as acquisition, and employs Charlene to transfer the external hard drive data to the Fairweather's' network and process it to a daily QC product, which is typically a bathymetric surface with data from that acquisition platform. Charlene automates the following tasks between raw data collection and the final daily product:

1. Perform verification of raw data
2. Build a deliverable directory structure
3. Transfer and verify raw data
4. Convert the Kongsberg .all file to CARIS HIPS HDCS format
5. Apply delayed heave from the POS files
6. Generate and apply SBET and SBET RMS files
7. Georeference Data which includes
Apply sound speed correctors
Apply a GPS Tide via a separation model (VDATUM or ERTDM)
Compute the Total Propagated Uncertainty
8. Generate a CARIS CSAR bathymetric surface from the data

Once Charlene has completed, night processors inspect the data in CARIS HIPS to ensure all correctors have been properly applied, and that the final products reflect observed conditions to the standards set by the relevant OCS guidance. Bathymetric surfaces are reviewed to ensure that all data quality problems are identified and resolved if possible, and all submerged features are accurately represented.

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

The field unit's final deliverable bathymetric surface is a variable resolution (VR) Combined Uncertainty and Bathymetric Estimator (CUBE) surface for complete coverage surveys. The CUBE surface's resolution, depth range, and parameters follow HSSD section 5.2.2. The bathymetric surfaces are generated following the application of all correctors highlighted above in Section C.1.1.

C.1.4.2 Depth Derivation

Multibeam data were reviewed and analyzed in CARIS HIPS Subset Editor, utilizing the generated CUBE surfaces for directed data editing to reject data that led to fliers in the surface. The surfaces were also used to demonstrate coverage and to check for errors due to tides, sound speed, attitude, and timing.

Vessel heading, attitude, and navigation data were reviewed in HIPS Navigation Editor and Attitude Editor if deemed necessary upon review of surfaces. Where necessary, data spikes (fliers) or gaps in heading, attitude, or navigation data were manually rejected or interpolated for small periods of time. Any editing of this nature is outlined in the Descriptive Report for the particular survey.

Hydrographers may designate soundings if the bathymetric surface fails to represent navigationally significant depths and features. Designated soundings are selected following the criteria in section 5.2.1.2.3 of the HSSD.

C.1.4.3 Surface Computation Algorithm

All VR surfaces are generated via the Ranges estimation method within CARIS HIPS and SIPS. This algorithm grids data based on the resolution requirements for each depth range, adhering to the specifications in the HSSD. The following options are selected for the Ranges Estimation Method:

- Range/Resolution File: NOAA_DepthRanges_ObjectDetection.txt (for object detection surveys) or NOAA_DepthRanges_CompleteCoverage.txt (for complete coverage surveys)

- Range Estimation Method: Percentile

- Input Band: Depth

- Output Vertical Coordinate System: Unknown

- Keep Partial Bins: Checked

- Maximum Grid Size: 128

- Minimum Grid Size: 4

The population method utilized for the generation of the Ranges surfaces was CUBE. The following options were selected for the generation of each surface:

- Disambiguation Method: Density and Locale

- IHO Order: S44 Order 1a

- Display Bias: Highest

- CUBE Configuration: NOAA_VR

The CUBE Configuration utilized comes from the CUBEParams_NOAA_2021.xml file included within the Caris_Support_Files_2021v1. This file contains the parameters necessary to create CUBE surfaces meeting the requirements as stated in the HSSD.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

The Kongsberg EM 2040 system logs backscatter to the .all file concurrently with all multibeam data. The HIC monitors the “Seabed Image” tear-off to ensure adequate backscatter imagery is obtained during survey acquisition. The HIC also documents all Kongsberg system frequency changes to aid in file segregation prior to backscatter processing.

Data Processing Methods and Procedures

Backscatter data are processed with the Fledermaus Geocoder Toolkit (FMGT) software using the subsequent steps:

- A new project was created for each frequency used by each vessel within the sheet. For example, if Launch 2806 acquired data in 200 kHz and 300 kHz, two separate projects must be created.

- The vessel pulse mode correction parameters of each frequency for each vessel were set to create a smoother appearance of the imagery between mosaics created for each project within the sheet. These parameters were based on an analysis performed by ship's personnel of data collected over a calibration line during HSRR. This allowed for the generation of single-frequency mosaics across platforms.

- Lines were imported into FMGT, combining the .all files with the HDCS files created in CARIS, resulting in the generation of GSF files.

- A mosaic in floating point GeoTIFF format was created for each project from the imported GSF files. The backscatter mosaic’s minimum resolution depends on the acquisition frequency, using the equation provided in HTD 2018-3. The minimum resolutions for all systems utilized by the field unit were as follows: 6 meters for 100 kHz, 3 meters for 200 kHz, 2 meters for 300 kHz, and 1.5 meters for 400 kHz.

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

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Vessel attitude is measured by the Applanix POS MV and recorded in both SIS .all files (for real-time correctors) and POS MV .000 files (for delayed heave data). The POS MV continuously logs data to a USB drive throughout the survey day. A five minute buffer period of POS MV data is acquired preceding and following any sonar data acquisition to permit proper initialization of filters for delayed heave and PPK solutions.

Data Processing Methods and Procedures

Attitude correctors applied after initial CARIS HIPS conversion use the raw POS MV attitude data recorded in the Kongsberg data files (.all). The .000 delayed heave file logged by the POS MV is separately loaded into HIPS, replacing the real-time heave values recorded in the raw data.

This .000 file is then post processed in Applanix POSPac to generate a Smoothed Best Estimate of Trajectory (SBET), adjusting the integrated positioning and inertial measurements with Trimble CenterPoint Real-Time Extended (RTX) differential correctors. Trimble RTX uses a network of globally distributed high-performance GNSS receivers that generate the precise orbit, clock, and observation biases for any location on Earth, eliminating the need to establish local reference stations. Post processed RTX corrections are available an hour after data acquisition. The SBET file is exported from WGS84 to NAD83, and then run through the POSPac AutoQC tool in Pydro to evaluate the quality of the ERS vessel positioning. Any short-term unresolvable errors in the GNSS height and uncertainty time series data are manually replaced with an interpolated signal derived from differential heave, dynamic draft, and water level data. Once this quality assessment has been completed, the SBET and corresponding RMS uncertainty file containing the recomputed vessel navigation and ellipsoidal height are applied to the data in CARIS HIPS.

Once SBETs have been applied to the data, a GPS vertical adjustment is computed in CARIS HIPS, utilizing a vertical Datum Model (VDATUM) supplied by HSTB to reduce the data from the ellipse to MLLW. The data are then reviewed for consistency, ensuring that no vertical offsets due to artifacts in the SBET or improper application exist.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

HSL sound speed profiles are captured with the SeaBird Electronics SBE19plusV2 CTD. All HSLs have small swing-arm davits with 24-volt electric winches for deploying and recovering the CTD profilers. Sound speed profiles are collected while the launch is at rest.

Sound speed casts are taken at least once every four hours during multibeam survey operations in accordance with section 3.5.1 of the FPM. All platforms collect sound speed casts according to observed variations in the water column and any changes in survey location that would influence sound speed differences in excess of the accepted 2 m/s range in accordance with section 5.2.3.3 of the HSSD. Changes are monitored through the real-time surface sound speed view in Sound Speed Manager (SSM) and the data view in SIS. SSM provides a geographic view of changes in surface sound speed which assists in the targeting of casts for zoning water masses. The CastTime algorithm is also employed in SSM to guide cast frequency. In SIS, the user is warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

Data Processing Methods and Procedures

Sound speed cast processing is performed via the HydrOffice Sound Speed Manager (SSM) application. HSL casts are downloaded from the CTD and converted from their raw binary sensor measurements (.hex) to standard units (.cnv) using a manufacturer supplied calibration file (.xmlcon). These files are then smoothed using 1 meter cosine averaged depth bins and saved to the SSM database. The smoothing eliminates errors near the surface resulting from wave action and engine cooling water outflow. Once the profiles have been loaded and filtered or inspected, they are transmitted by SSM over the network to the Kongsberg HWS for application in SIS. SSM confirms reception, or the hydrographer may inspect the updated file name in the "Runtime Parameters" tear-off upon network errors.

All sound speed casts saved to the SSM database are exported into a .svp file that is readable in CARIS HIPS. Casts are progressively concatenated per sheet, including all casts taken within the sheet limits. This concatenated file is applied to all HDCS data using the "Nearest in distance within time" algorithm, using the time interval suggested by the Hydrographer in Charge during acquisition. This time interval is generally four hours, but may be reduced if necessitated by environmental conditions.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

All HSLs use SVP 71 probes. The SVP probes supply the MBES with real-time values, which applies a median filter and corrects for the flat-faced transducer's refraction. During acquisition, the HIC adjusts this filter's length to capture variability while suppressing bubble sweep-down errors. HICs monitor the surface sound speed for a > 2 m/s change, which requires a new cast using the methods described in C.5.1.

Data Processing Methods and Procedures

Surface sound speed data are not post-processed.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

The final uncertainty for soundings is calculated within CARIS HIPS using the Compute TPU tool. CARIS HIPS computes the TPU based on the vessel's static and dynamic measurements, project specific tidal referencing, ERS positioning, and sound speed values. The TPU section of the HVF captures fixed estimates of uncertainty. Uncertainty values for the multibeam and positioning systems are compiled from manufacturer specification sheets for each sensor, and from those set forth in Section 4.2.9 of the 2020 FPM. CARIS HIPS also applies a sonar device model for uncertainty values associated with the sounding detections.

Vertical uncertainty is provided in the Project Instructions is associated with the VDatum model supplied.

Sound speed uncertainty is estimated based on cast frequency and distribution, with a typical value of 2 m/s employed unless otherwise specified in the DR. Real-time sonar uncertainties are provided via EM 2040 MBES data, and positioning errors are provided via the Applanix Delayed Heave RMS. Following postprocessing of the real-time vessel motion, recomputed uncertainties of navigation and ellipsoidal height are applied in CARIS HIPS via a Smoothed Best Estimate of Trajectory (SBET) RMS file generated in Applanix POSPac.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		FA 2805, 2806, 2807, 2808	S220
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*
All Vessels	Real-time sonar uncertainties are provided via EM 2040 MBES data, and positioning errors via Applanix Delayed Heave RMS.

C.7 Shoreline and Feature Data

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

The composite source file (CSF) in S-57/.000 format provided with the Project Instructions is the primary source for shoreline feature verification. The original project file is imported into CARIS HIPS and SIPS, converted to a .hob file, clipped to the sheet limits for the specific survey, and named H#####_Feature_File.hob to be utilized during field verification. Additionally, all bottom samples to be investigated are provided to the field in the project reference file (PRF). All hob files are re-exported to S-57/.000 format for data submission.

Fairweather personnel conduct limited shoreline verification during periods when the tide is less than 0.5m above Mean Lower-Low Water (MLLW) as directed by section 3.5.5.3 of the FPM. Detached positions (DPs) are acquired and edits to the daily field feature files are recorded on boat sheets. An inshore limit buffer line, defined by the distance seaward from the Mean High Water (MHW) line at the scale of the largest chart in the area, is provided with the Project Instructions. This inshore limit buffer line is used in the shoreline acquisition software and on the boat sheet as a reference, and is utilized as described in section 1.1.2 of the HSSD. The NALL is determined in the field as the farthest offshore of one of the following; the MHW inshore limit buffer specified above, the 3.5-meter depth contour, or the inshore limit of safe navigation as defined by the HSSD. All shoreline features from the CSF seaward of the NALL are verified (including an update to depth and/or position as necessary) or disproved during operations. Features inshore of the NALL are not addressed, and features of an ambiguous nature include remarks for further clarification.

Specifically assigned features may be investigated that are inshore of the NALL in accordance with the associated instructions for a given project area.

Detached positions (DPs) acquired during shoreline verification indicate new features, revisions to source features, or source features not found in the field. They are recorded as targets in HYPACK and on boat sheets.

Data Processing Methods and Procedures

During shoreline verification, field detached positions (DP) are acquired as HYPACK .tgt files. Tidal corrections for new/updated heights on features are applied in PydroXL via the Shoreline Attribution Machine (SHAM) program within Charlene. This program takes the observed time (obstim) and observed depth (obsdept) attributes from the Final Feature File that are populated following field investigation and uses the TCARI grid or ERTDM separation model to perform a tidal correction.

New features and any updates to the composite source shoreline, such as ledges or reefs, are acquired or digitized with S-57 attribution and compiled from the field daily files into the H#####_FFF.hob. Updates to source shoreline features primarily include a change in depth/height, position, or S-57 classification. If the position of a feature changes, the existing feature is deleted and a new feature created in the new location. Any changes to depth/height or S-57 classification are done so as an update to the S-57 object with the inclusion of NOAA’s object attributes. The SORIND and SORDAT S-57 attribute fields for new features or modified source features are updated to reflect the information for the associated survey number and date (US,US,graph,H#####). All new or modified features are S-57 attributed as applicable and descriptively attributed as New or Update respectively. All unmodified source features retain their original SORIND and SORDAT values. Assigned features that are addressed but not updated are descriptively attributed as "Retain" and unaddressed assigned features are attributed as "Not Addressed." Short descriptive comments taken from the boat sheets or DP forms are listed under the Remarks field.

For significant features that deserve additional discussion, the Hydrographer may include a recommendation to the cartographer in the Recommendations field, along with the notes and investigation methods provided in the Remarks field. Features that are disproved or that do not adequately portray the shoreline are descriptively attributed as Delete in the H#####_FFF.hob layer. Features with the attribution of Delete retain their original SORIND and SORDAT values and include a recommendation from the Hydrographer along with an informative remark.

Images are named in accordance with the convention set forth in HTD 2018-5. They are included with the survey data and stored in the Multimedia folder with the deliverables. References to the images are comma delimited and listed with the file extension in the "Images" attribute for the specific feature. The H#####_FFF.hob along with CARIS HIPS BASE surface(s) are reviewed to compare MBES coverage and features simultaneously. The current NOAA object catalog is used for all CARIS software for processing and the version is documented in the individual Descriptive Reports, along with any deviations in shoreline processing from those listed above. The final shoreline deliverable is an S-57 (*.000) file included with the processed data.

C.8 Bottom Sample Data

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

HSD-OPS recommends bottom sample sites in the project reference file (PRF). The field unit examines these proposed sample sites and potentially eliminates some based on the actual depths found during survey operations (if deeper than 80 m), or supplements them with good anchorage positions located by the ship. Bottom sample locations may also be adjusted by the field unit to investigate areas of interest as determined through analysis of the backscatter data in an effort to ground truth returns of different intensities.

Field units acquire bottom samples with a Kahlsico Mud Snapper and Torpedo grab sampler, as described in Section A.8.1. This method utilizes a hand held sampler to acquire a fist sized sample of the seafloor. Once brought to the surface, the physical sample analysis classifies the sediment type for S57 attribution classification, with the most prevalent bottom type listed first. Attribution is recorded in the field on a bottom sample form and may also be entered into a CARIS feature layer. The sample site's "Nature of Surface" (NATSUR) is characterized as “unknown” upon the field unit’s failure to obtain a sample after three attempts. Field units return samples after completing analysis.

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

All bottom samples are entered or imported into the Final Feature File as Seabed Area (SBDARE) point features and attributed to match the recorded characteristics. Sheet managers link the sample images to the corresponding S-57 SBDARE attributed feature within the Final Feature File.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Preliminary data cleaning is performed daily during night processing following acquisition, addressing the most blatant fliers and blowouts. Cleaning is primarily done in Subset Editor, rejecting data that cause fliers in the CUBE grid. Following this gross cleaning, Flier Finder, part of the QC Tools package of HydrOffice, is used to assist the search for spurious soundings. Flier Finder is run iteratively until all remaining flagged fliers are deemed to be valid aspects of the steep slopes and dynamic nature of the seafloor. Additionally, the uncertainty, hypothesis count, hypothesis strength, and node standard deviation child layers of the surface in CARIS HIPS are utilized to identify potential problem areas.

D.1.2 Designated Sounding Selection

In depths less than 20 meters in areas of navigational significance where the bathymetric surface does not adequately depict the depth for the given area, a designated sounding may be selected. Designated soundings are selected in accordance with section 5.2.1.2.3 of the HSSD. Detailed designated sounding searches in Subset Editor are only performed in regions expected to contain variation not captured in the standard grid, or when searching for known features. Generation of higher resolution grids than required for the depth range may be used to guide the search for designated soundings.

D.1.3 Holiday Identification

Pydro's "Holiday Finder" tool scans the CUBE surfaces for any empty grid nodes that are surrounded by populated nodes, and flags holidays dependent on the criteria set by the coverage requirements. All flags are then visually inspected to determine the validity of each holiday, and all confirmed holidays are addressed either by acquiring additional data over the gaps, or explaining the cause and likelihood of hazards within each gap.

D.1.4 Uncertainty Assessment

Pydro’s “Grid QA v.5” function verifies that all surfaces meet HSSD’s uncertainty specifications. This tool plots node percentage histograms, which demonstrate surface compliance with the uncertainty standards set forth in the HSSD.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

As a quality control measure, approximately 4% (for complete coverage surveys) of the linear nautical mile total of mainscheme multibeam lines are run on each survey as crosslines. Crosslines are run in accordance with Section 5.2.4.2 of the HSSD. Following acquisition, a surface containing strictly data from mainscheme lines and a surface containing strictly data from crosslines are generated and analyzed with the Compare Grids tool in Pydro. This tool analyzes the difference between the two grids and outputs a difference surface between the depths, as well as a second surface that contains the fraction of NOAA allowable error represented by that depth difference for each node. Additionally, statistics/distribution summary plots of the difference surface and the fraction of allowable error are generated to provide easily interpretable analyses of the differences between the surfaces.

D.1.5.2 Junctions

Survey managers perform junction analyses between the current survey and all adjacent contemporary surveys. To ensure proper overlap between surveys, approximately one bathymetric swath of overlap is acquired at each junction. Surface based and statistical analysis of the junctions is performed through the Compare Grids tool as described in D.1.5.1.

D.1.5.3 Platform to Platform

Agreement and continuity of data collected between platforms is visually investigated by the survey manager to ensure consistency and highlight any potential biases in the data. To aid in the determination of potential biases, the depth child layer of the surfaces is inspected with an increased vertical exaggeration, generally between five and ten times greater.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Processed backscatter mosaics are inspected in CARIS HIPS to ensure that no data were omitted during processing, and that no errors occurred in mosaic generation.

D.2.2 Contact Selection Methodology

Not applicable.

E. Approval Sheet

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

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies noted herein.

Approver Name	Approver Title	Date	Signature
CAPT John Lomnicky, NOAA	Chief of Party	11/06/2022	
LT Michael Card, NOAA	Operations Officer	09/22/2021	

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	FA_2021_Wiring_Diagram.pdf 280x - 2022.pdf
Sound Speed Sensor Calibration	DQA_LOG_Master.pdf
Vessel Offset	2022_2805_Offset_Conversion_Workbook.xlsx 2022_2806_Offset_Conversion_Workbook.xlsx 2022_2807_Offset_Conversion_Workbook.xlsx 2022_2808_Offset_Conversion_Workbook.xlsx FA_S220_Offsets_2022.xlsx 2021_Waterline_measurements.pdf Dynamic_Draft_Table_2019.pdf
Position and Attitude Sensor Calibration	2805_POS_GAMS_Report_2022_Dn108.xls 2806_POS_GAMS_Report_2022_Dn102.xls 2807_POS_GAMS_Report_2022_Dn096.xls 2808_POS_GAMS_Report_2022_Dn102.xls S220_POS_GAMS_Report_2021_Dn068.pdf
Echosounder Confidence Check	HSRR_2022_Reference_Surfaces.xlsx
Echosounder Acceptance Trial Results	N/A

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-M328-FA-22
Time Frame:	November - November 2022

LOCALITY

State(s):	California Oregon
General Locality:	Offshore Oregon and near Channel Islands National Marine Sanctuary

2022

CHIEF OF PARTY
CAPT John "Jay" Lomnicky

Table of Contents

List of Figures

Data Acquisition and Processing Report

NOAA Ship *Fairweather*
Chief of Party: CAPT John "Jay" Lomnicky
Year: 2022
Version: 1.0
Publish Date: 2023-01-30

A. System Equipment and Software

A.1 Survey Vessels

A.1.1 FA 2805

Vessel Name	FA 2805	
Hull Number	2805	
Description	FA 2805 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 1: FA 2805

A.1.2 FA 2806

Vessel Name	FA 2806
Hull Number	2806
Description	FA 2806 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.
Dimensions	*LOA*: 8.6 meters *Beam*: 3.5 meters *Max Draft*: 1.1 meters

Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 2: FA 2806

A.1.3 FA 2807

Vessel Name	FA 2807
Hull Number	2807
Description	FA 2807 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.

Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 3: FA 2807

A.1.4 FA 2808

Vessel Name	FA 2808	
Hull Number	2808	
Description	FA 2808 is a Jenson “Type 1” aluminum hydrographic survey launch (HSL) aboard S220. It has an 8.64 meter aluminum hull, a 13 passenger capacity, and a weight of 15,500 lbs. A 490 HP Cummins Diesel engine with a 2' diameter fixed pitch propeller powers the HSL to reach a 20 kt cruising speed.	
Dimensions	*LOA*	8.6 meters
	Beam	3.5 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2021-01-27
	Performed By	Reality Documentation Solutions

Figure 4: FA 2808

A.1.5 NOAA Ship Fairweather

<table>
<tr><td>Vessel Name</td><td colspan="2">NOAA Ship Fairweather</td></tr>
<tr><td>Hull Number</td><td colspan="2">S220</td></tr>
<tr><td>Description</td><td colspan="2">NOAA S Fairweather (S220) is a 70.4 meter oceanographic research vessel owned and operated by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA). It has a welded steel and ice strengthened hull for an ABS classification of #A1, #AMS.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>70.4 meters</td></tr>
<tr><td>Beam</td><td>12.8 meters</td></tr>
<tr><td>Max Draft</td><td>12.8 meters</td></tr>
</table>

Most Recent Full Static Survey	*Date*	2022-01-01
	Performed By	IMTEC Group, Ltd.

Figure 5: NOAA Ship Fairweather S220

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM 2040

HSLs 2805, 2806, 2807, and 2808 are each equipped with a Kongsberg EM 2040 MBES. The EM 2040 is capable of operating at low frequency (200 kHz), intermediate frequency (300 kHz), and high frequency (400 kHz), with maximum swath coverage of 150°. At the common usage frequency of 300 kHz, the beam width is 1° for both TX and RX. The system forms 256 beams, with dynamic focusing employed in the near field. The system forms 400 soundings per swath with an equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range for the EM 2040 is 0.5 to 600 meters.

Manufacturer	Kongsberg			
Model	EM 2040			
Inventory	*2805*	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	255	354
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2806	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	249	351
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2807	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	247	355
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22
	2808	*Component*	Transmit Array	Receive Array
		Model Number	EM 2040	EM 2040
		Serial Number	248	356
		Frequency	200/300/400 kHz	200/300/400 kHz
		Calibration	2022-04-22	2022-04-22
		Accuracy Check	2022-04-22	2022-04-22

Figure 6: EM 2040 Transceiver Array

A.2.1.2 Kongsberg EM 712

S220 has a hull-mounted Kongsberg EM 712 multibeam echosounder (MBES), which operates at sonar frequencies in the 70 to 100 kHz range. The maximum utilized across-track swath coverage is 140° with a published maximum depth of > 2500 meters. The along track beam width configuration is ½° with a receive beam width of 1°. The system forms 400 soundings per swath with equidistant beam spacing and dynamic focusing employed in the near field. The transmit beams are divided into three sectors which transmit sequentially within each ping, using distinct frequencies to maximize range capability and to suppress interference from multiples of strong bottom echoes. The typical operational depth range of the EM 712 is 10 to 2500 meters.

<table>
<tr><td>Manufacturer</td><td colspan="4">Kongsberg</td></tr>
<tr><td>Model</td><td colspan="4">EM 712</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">S220</td><td>Component</td><td>Transmit Array</td><td>Receive Array</td></tr>
<tr><td>Model Number</td><td>EM 712</td><td>EM 712</td></tr>
<tr><td>Serial Number</td><td>399431</td><td>991674</td></tr>
<tr><td>Frequency</td><td>70-100 kHz</td><td>70-100 kHz</td></tr>
<tr><td>Calibration</td><td>2022-03-01</td><td>2022-03-01</td></tr>
<tr><td>Accuracy Check</td><td>2022-05-06</td><td>2022-05-06</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 POS MV 320 V5

The POS MV V5 calculates position, heading, attitude, and vertical displacement (heave) of a vessel. It consists of a rack mounted POS Computer System (PCS), a bolted down IMU-200 Inertial Measurement Unit (IMU), and two GNSS antennas corresponding to GNSS receivers in the PCS.

Manufacturer	Applanix POS MV
Model	320 V5

Inventory

2805	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
	Model Number	320 V5	L200	GA830	GA830
	Serial Number	8198	5222	21374	21375
	Calibration	2022-04-18	2022-04-18	2022-04-18	2022-04-18
2806	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
	Model Number	320 V5	L200	GA830	GA830
	Serial Number	8197	5224	23164	23168
	Calibration	2022-04-12	2022-04-12	2022-04-12	2022-04-12
2807	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
	Model Number	320 V5	L200	GA830	GA830
	Serial Number	8195	5225	9968	9962
	Calibration	2022-04-06	2022-04-06	2022-04-06	2022-04-06
2808	*Component*	PCS	IMU	GNSS Antenna	GNSS Antenna
	Model Number	320 V5	L200	GA830	GA830
	Serial Number	8196	5227	16724	16727
	Calibration	2022-04-06	2022-04-06	2022-04-06	2022-04-06

Figure 7: POS MV 320 V5 System

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

A.6.1.1 AML Oceanographic MVP 200 MVP 200

The MVP 200 is a self-contained system capable of sampling water column profiles to depths of 200 meters from a vessel moving at up to 12 kts, achieving greater depths at slower speeds. During towed operation, the MVP 200 can be controlled by computer without the requirement for personnel on deck. The system consists of a single sensor free fall fish, an integrated winch and hydraulic power unit, a towing boom, and a remotely located computer controller with a user interface. Fairweather's MVP fish is equipped with an AML Oceanographic Micro-CTD sensor capable of acquiring conductivity, temperature, and depth (CTD) profiles to determine the speed of sound and absorption in the water column, primarily to correct bathymetry data acquired with the EM 712 MBES

<table>
<tr><td>Manufacturer</td><td colspan="3">AML Oceanographic MVP 200</td></tr>
<tr><td>Model</td><td colspan="3">MVP 200</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S220</td><td>Component</td><td>CTD Sensor</td></tr>
<tr><td>Model Number</td><td>Micro-CTD</td></tr>
<tr><td>Serial Number</td><td>8817</td></tr>
<tr><td>Calibration</td><td>2022-04-22</td></tr>
</table>

Figure 8: MVP 200 System

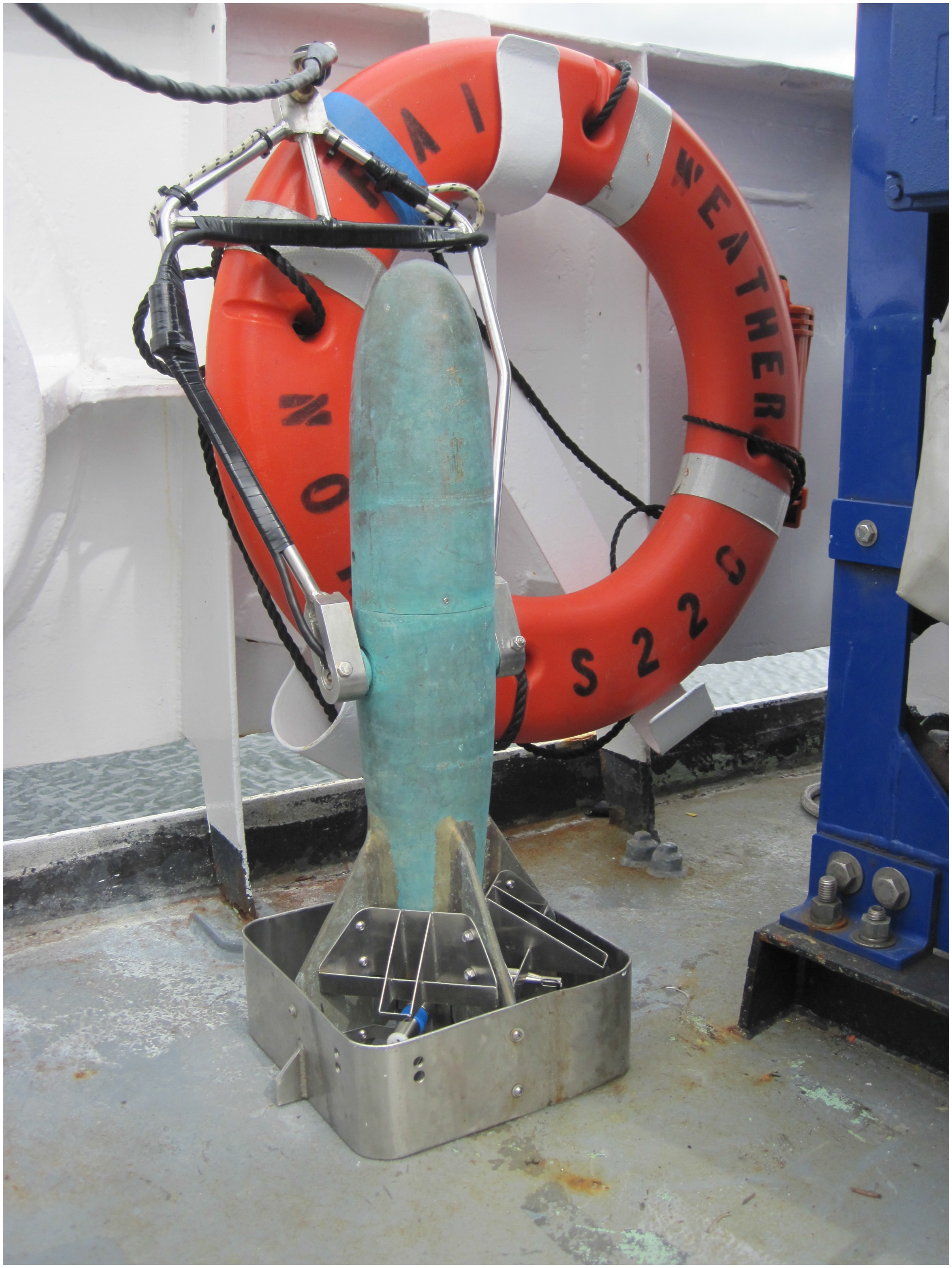

Figure 9: Single Sensor Free Fall Fish

A.6.2 CTD Profilers

A.6.2.1 Sea-Bird Electronics SBE CTD

Fairweather utilizes SBE 19plusV2 SeaCAT sound speed profilers to acquire conductivity, temperature, and depth (CTD) data throughout the water column. The SBE 19plusV2 have pressure sensors rated to 600 m. All SeaCAT sound speed profilers were calibrated by the manufacturer during the 2020 -2021 winter repair period. The survey department performs quality checks and comparison casts on any instruments on a routine basis.

Manufacturer	Sea-Bird Electronics				
Model	SBE CTD				
Inventory	*Component*	CTD	CTD	CTD	CTD
	Model Number	SBE 19plusV2	SBE 19plusV2	SBE 19plusV2	SBE 19plusV2
	Serial Number	7634	6121	6122	7370
	Calibration	2022-06-13	2022-06-13	2022-06-13	2022-06-13

Figure 10: SBE 19plusV2

A.6.3 Sound Speed Sensors

A.6.3.1 Teledyne RESON SVP-71

The SVP-71 is a direct-reading sound speed probe with a 125 mm sound transmission path. The unit's housing composition is hard, anodized, sea water resistant aluminum. This sensor is mounted in proximity to the multibeam transceiver on each HSL, providing real-time surface sound speed values for refraction corrections.

Manufacturer	Teledyne RESON		
Model	SVP-71		
Inventory	*2805*	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	3511355
		Calibration	2019-05-28
	2806	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	2008038
		Calibration	2019-05-28
	2807	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	1213046
		Calibration	2019-05-28
	2808	*Component*	Surface Sound Speed Sensor
		Model Number	SVP-71
		Serial Number	1713034
		Calibration	2019-05-28

A.6.3.2 Teledyne RESON SVP-70

The SVP-70 is a direct-reading sound speed probe with a 125 mm sound transmission path. The unit’s housing is composed of robust titanium, which reduces marine growth on these continually submerged sensors. S220 has two sensors in proximity to the ship’s multibeam transducer.

Manufacturer	Teledyne RESON			
Model	SVP-70			
Inventory	*S220*	*Component*	Surface Sound Speed Sensor	Surface Sound Speed Sensor
		Model Number	SVP-70	SVP-70
		Serial Number	0614171	0614172
		Calibration	2019-03-29	2019-03-29

A.6.3.3 Lockheed Martin Deep Blue

A standard Expendable Bathythermograph (XBT) uses an electrical connection between the probe and the processor/recorder and a sea water ground to calculate temperature or sound velocity data to be telemetered to the ship-board data processing equipment. This system is used in sensitive areas where the danger of a normal CTD striking marine structures is too great.

Manufacturer	Lockheed Martin		
Model	Deep Blue		
Inventory	*S220*	*Component*	XBT
		Model Number	300686-1
		Serial Number	Various
		Calibration	2022-12-01

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*
Teledyne CARIS	HIPS and SIPS	11.4.6	Processing
Teledyne CARIS	BASE Editor	5.5.25	Processing
Applanix	MV POSView	10.2	Acquisition
Applanix	POSPac	8.7	Processing
Quality Positioning Services BV (QPS)	Fledermaus Geocoder Toolbox (FMGT)	7.10.2	Processing
Kongsberg Maritime AS	Seafloor Infomation System (SIS)	5.9	Acquisition
NOAA Hydrographic Systems and Technology Branch	Pydro Explorer	19.4	Acquisition and Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Kahlisco Mud Snapper

The Kahlsico Mud Snapper is a hand held bottom sampler that is used aboard all Fairweather launches.

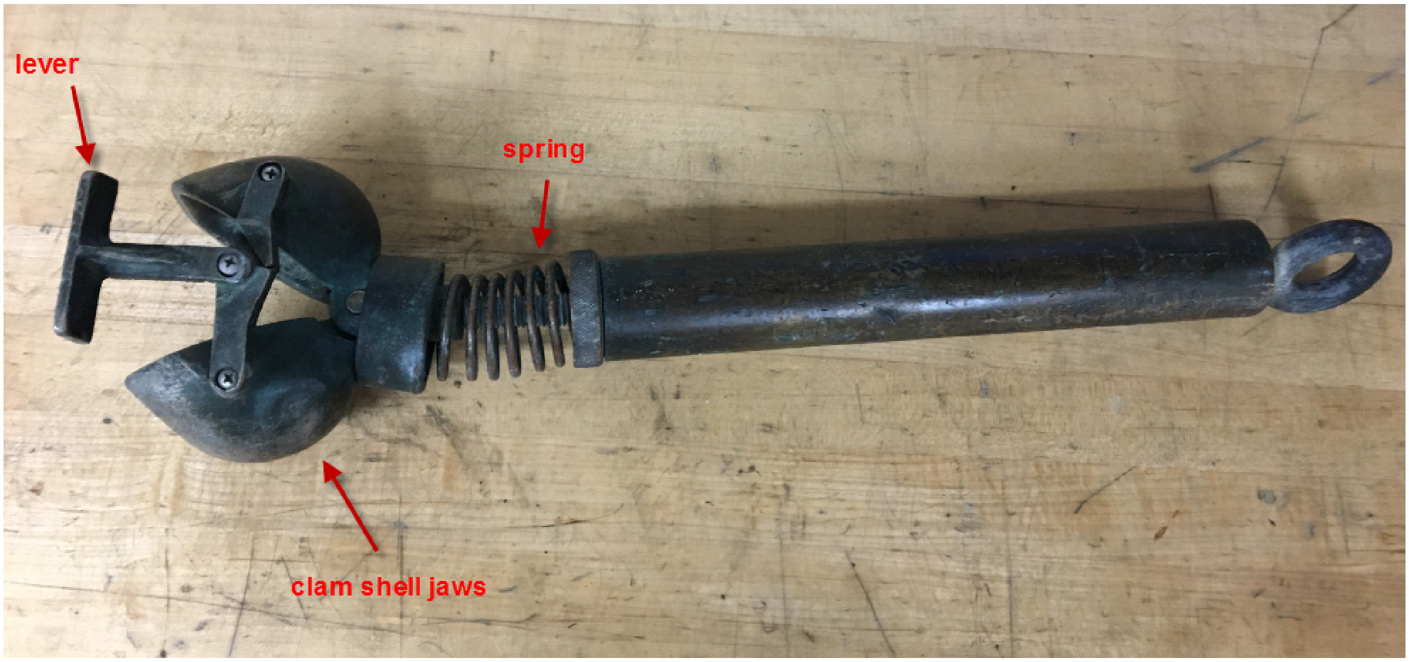

Figure 11: Mud Snapper style grab sampler used about NOAA Ship Fairweather launches.

A.8.1.2 Kahlsico Torpedo Sampler

The Kahlsico Torpedo Sampler is a hand held bottom sampler that is used aboard all Fairweather launches.

Figure 12: Torpedo style grab sampler used about NOAA Ship Fairweather launches.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

B.1.1 Vessel Offsets
The reference point for all positioning, attitude, and sonar systems maintained by Fairweather is co-located at the phase center of the sonar transmitter and rotated to the face of the transducer for the EM 2040 installations on the HSLs and the ships EM 712. A single reference point simplifies downstream processing and reduces potential errors from incorrect entered offset values in the CARIS HIPS Vessel File (HVF). This was achieved for position and attitude by entering the surveyed translational and rotational

offsets of the IMU and GNSS antennae for each platform into the respective POS configuration. Thus the position and attitude reported by the POS, including heave and delayed heave, are valid at the transmit array. Furthermore, this reference point is the center of rotation in POS for the purposes of applying the heave filter, as the reference to center of rotation field is zero.

Rotational and translational offsets for the HSL EM 2040 systems, offsets were derived from a combination of values from the 2010 NGS survey of permanent control benchmark points on the launch hull, engineering drawings of the sonar mount, and directly measured offsets from control points to equipment interfaces. Due to the relatively short baselines between HSL systems, minor differences resulting from survey methods or CAD drawing discrepancies are not expected to introduce significant error. Rotational and translational offsets for the HSL EM 712 system, offsets were derived from a combintiaon of values from the 2022 NGS survey durign the instillation of the EM 712.

Transducer and navigation offsets and alignments were entered in SIS according to the EM 2040/EM 712 transmitter reference frame. The translational and angular offsets of the receiver array (labeled “RX Transducer”) relative to the transmit array were entered into SIS. The location of the reference point at the transmit array allows the translational and angular offsets from the transmit array (TX Transducer) to the reference frame to be zero. Since the reference point of the POS was configured to be located at and aligned with the transmit array centered frame, the offsets for the position and attitude data from the POS are also zero in SIS. With this approach, any residual misalignment between the EM 2040/EM 712 and the IMU discovered in a patch test (see Section B.3.1) was added to the IMU alignment with respect to the reference frame in the POS configuration, maintaining the transmit array as aligned with the reference frame.

Entries in the CARIS HVF account for the offset between the transmit and receive arrays for the EM 2040/EM 712 systems, entered under the SVP 2 section so processing of raw range-angle data is correct after sound speed profile corrections are applied. All other vessel offset values have been set to zero and apply to “No” to avoid double-correction. Offsets to the IMU and primary GNSS antenna are also entered under the TPU section, but this is only used for estimates of uncertainty and not positioning of soundings.

B.1.1.1 Vessel Offset Correctors

Vessel	FA 2805
Echosounder	Kongsberg EM 2040 300 kHz Mode
Date	2022-04-20

Offsets

		Measurement	*Uncertainty*
MRU to Transducer	*x*	0.201 meters	0.006 meters
	y	0.159 meters	0.006 meters
	z	0.499 meters	0.006 meters
	x2	-0.102 meters	N/A
	y2	0.063 meters	N/A
	z2	0.484 meters	N/A
Nav to Transducer	*x*	0.904 meters	0.006 meters
	y	0.949 meters	0.006 meters
	z	3.694 meters	0.006 meters
	x2	0.601 meters	N/A
	y2	0.853 meters	N/A
	z2	3.679 meters	N/A
Transducer Roll	*Roll*	0.000 degrees	
	Roll2	0.000 degrees	

Vessel	FA 2806			
Echosounder	Kongsberg EM 2040 300 kHz Mode			
Date	2022-04-20			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.196 meters	0.006 meters
		y	0.146 meters	0.006 meters
		z	0.503 meters	0.006 meters
		x2	-0.106 meters	N/A
		y2	0.048 meters	N/A
		z2	0.491 meters	N/A
	Nav to Transducer	*x*	0.911 meters	0.006 meters
		y	0.979 meters	0.006 meters
		z	3.694 meters	0.006 meters
		x2	0.609 meters	N/A
		y2	0.880 meters	N/A
		z2	3.682 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	FA 2807			
Echosounder	Kongsberg EM 2040 300 kHz Mode			
Date	2022-04-20			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.198 meters	0.006 meters
		y	0.141 meters	0.006 meters
		z	0.506 meters	0.006 meters
		x2	-0.098 meters	N/A
		y2	0.034 meters	N/A
		z2	0.515 meters	N/A
	Nav to Transducer	*x*	0.907 meters	0.006 meters
		y	0.950 meters	0.006 meters
		z	3.691 meters	0.006 meters
		x2	0.611 meters	N/A
		y2	0.843 meters	N/A
		z2	3.700 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	FA_S220_EM712			
Echosounder	Kongsberg Simrad EM710			
Date	2022-05-06			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	1.720 meters	0.002 meters
		y	8.423 meters	0.002 meters
		z	4.649 meters	0.002 meters
		x2	1.829 meters	N/A
		y2	7.198 meters	N/A
		z2	4.648 meters	N/A
	Nav to Transducer	*x*	0.788 meters	0.002 meters
		y	20.219 meters	0.002 meters
		z	17.877 meters	0.002 meters
		x2	0.896 meters	N/A
		y2	18.994 meters	N/A
		z2	17.875 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	FA_2808_EM2040			
Echosounder	kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2022-04-01			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.199 meters	0.006 meters
		y	0.148 meters	0.006 meters
		z	0.498 meters	0.006 meters
		x2	-0.098 meters	N/A
		y2	0.048 meters	N/A
		z2	0.483 meters	N/A
	Nav to Transducer	*x*	0.926 meters	0.006 meters
		y	0.973 meters	0.006 meters
		z	3.685 meters	0.006 meters
		x2	0.628 meters	N/A
		y2	0.873 meters	N/A
		z2	3.671 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

No towed arrays were utilized for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

The static drafts (Waterline Height in the HVF) for HSLs are calculated based on steel tape and plumb bob measurements of the distance from benchmarks on the port and starboard quarter of the vessel to the waterline. These measurements were combined with the offset from these benchmarks to the sonar transducer to determine the waterline relative to the reference frame.

Measurements for the HSLs were conducted in March of 2021 in Seattle, WA. Values utilized for the 2022 season were based on an average of waterline values from 2017-2021. No significant stability alterations have occurred in this time period, with the added benefit of mitigating measurement error by using historical averages. The values and calculations for static draft of the HSLs are listed in the respective Waterline Measurement spreadsheets included within this report.

Static draft for S220 was conducted on March of 2021. Static draft for Fairweather is determined by using a laser rangefinder to measure the vertical distance to the water from benchmarks on the port and starboard E-Deck breezeway below the bridge wings. The measurements are translated to the transmitter reference frame using surveyed offsets to the benchmarks. The loading condition of the ship, particularly fuel and launches, has a more significant influence on static draft than just the launches. To compensate for static draft changes, static draft values are measured on S220 after any changes in fuel levels, and at the start of survey operations for each leg throughout the season. These measurements are taken while the vessel is at anchor or hove to.

For both the S220 and HSL sonar systems, static draft corrector values are entered in the Kongsberg SIS Installation Parameters window. In addition, waterline values are entered in the CARIS HVF. For S220, only the HVF is updated with the measurements taken throughout the field season, as this will override the SIS waterline during processing. The waterline value in CARIS will only be used during Sound Speed Correction. The Apply switch is set to “No” to avoid double application of the waterline value during HIPS merge.

B.2.1.1 Static Draft Correctors

Vessel	*Date*	*Loading*	*Static Draft*	
			Measurement	*Uncertainty*
FA 2805	2022-04-20	0.018 meters	-0.622 meters	0.014 meters
FA 2806	2021-03-20	0.018 meters	-0.624 meters	0.011 meters
FA 2807	2022-04-20	0.018 meters	-0.639 meters	0.010 meters
S220	2021-03-20	0.116 meters	-4.650 meters	0.128 meters
FA_S220_EM712	2022-05-06	0.116 meters	-4.410 meters	0.128 meters
FA_2808_EM2040	2022-04-01	0.018 meters	-0.631 meters	0.014 meters

B.2.2 Dynamic Draft

Dynamic draft data were not acquired in 2022 due to time constraints. The method Fairweather employs calculates the vessel's ellipsoid height change while transiting at different speeds in a straight line. The ellipsoid heights were determined using a Post Processed Kinematic (PPK) trajectory for each vessel through processing the recorded POS MV data with RTX correctors in Applanix POSPac MMS software. A third order polynomial curve was fit to the speed versus ellipsoid height data using a least squares fit through a script implemented in the POSPac AutoQC tool.

Dynamic draft data for the years 2020 and 2021 were analyzed but not found consistent or ultimately suitable for computation of dynamic draft models. Wind and sea state conditions did not allow for satisfactory achievement of the ellipsoidally referenced dynamic draft model (ERDDM) steps coupled with engine speed changes. Time and weather constraints did not allow for repeated attempts of acquiring dynamic draft data.

Since all launches are of essentially identical construction, a historical average for all launches using data from 2016-2019 was used to populate the CARIS HVF in order to reduce uncertainty introduced by wave action noise. Outlier vessel measurements with multiple delta draft values more than two standard deviations from the mean were removed from the average. The standard deviation of the residuals was used to determine the associated uncertainty in the measurement.

B.2.2.1 Dynamic Draft Correctors

Vessel	FA 2805, 2806, and 2807		FA_S220_EM712		FA_2808_EM2040	
Date	2019-04-11		2022-05-06		2019-04-11	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*
	0.00	0.00	0.00	0.00	0.00	0.00
	0.50	0.00	1.50	0.01	0.50	0.00
	1.00	0.01	2.00	0.03	1.00	0.01
	1.50	0.03	2.50	0.06	1.50	0.03
	2.00	0.04	3.00	0.08	2.00	0.04
	2.50	0.05	3.50	0.11	2.50	0.05
	3.00	0.06	4.00	0.14	3.00	0.06
	3.50	0.06	4.50	0.17	3.50	0.06
	4.00	0.05	5.00	0.20	4.00	0.05
	4.50	0.03	5.50	0.23	4.50	0.03
	5.00	0.00	6.00	0.25	5.00	0.00
	5.50	-0.03	6.50	0.27	5.50	-0.03
	6.00	-0.08			6.00	-0.08
	6.50	-0.13			6.50	-0.13
	7.00	-0.17			7.00	-0.17
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.03	0.03	0.03	0.10	0.03	0.03

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Patch test data for FA 2805, 2806, 2807, and 2808 were collected in Sausalito, CA, and in offshore San Francisco, CA for S220. Patch lines were along a slope and over a corresponding flat area with two parallel lines; one line was run twice in opposite directions while the parallel line was run once. Pitch and roll offsets utilized the lines run in reciprocal directions in the same location. The pitch calibration focused on the slope portion, and the roll calibration focused on the flat portion of the lines. The yaw offset focused the slope of two offset, parallel lines with the same heading.

Patch test data were converted in both QPS Qimera and CARIS HIPS, with multiple personnel determining patch test values. Qimera data were converted with vessel settings to zero and processed using the auto-calibration tool. Data were converted in CARIS HIPS using an HVF file with heave, pitch, roll, and timing values set to zero. Delayed heave, SBETs, SBET RMS, the most recent dynamic draft, sound speed correctors, and GPS tides via a VDATUM separation model were applied and the data were georeferenced before cleaning via Subset Editor.

Bias values were determined in the following order; pitch, yaw, roll. A minimum of five individual testers determined alignment test biases in CARIS and Qimera. A reviewer then examined these results for outlier elimination, after which the remaining results were averaged. The averaged values were entered as opposite sign rotations into the POS MV angular offsets in “IMU Frame w.r.t. Ref Frame" within the Lever Arms & Mounting Angles setup. The values for roll, pitch, and yaw correctors were entered as X, Y, and Z, respectively. These rotations are therefore applied to all raw orientation data output from the POS.

An additional examination of the correlation between a bathymetric roll artifact and the motion time series is used to solve for timing errors that are difficult to detect in the traditional patch test methodology. From these results, a constant timing delay is applied to all motion data in Kongsberg SIS. A value of 7 milliseconds is used for all HSLs and a value of 14 milliseconds for S220.

The values listed below are those entered into the POS MV, as the alignment values in the HVF are all set to zero.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>FA 2805</td></tr>
<tr><td>Echosounder</td><td>Kongsberg EM 2040</td></tr>
<tr><td>Date</td><td>2022-04-01</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><th></th><th>Corrector</th><th>Uncertainty</th></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>0.120 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Roll</td><td>-0.010 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Yaw</td><td>-0.430 degrees</td><td>0.120 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>FA 2806</td></tr>
<tr><td>Echosounder</td><td>Kongsberg EM 2040</td></tr>
<tr><td>Date</td><td>2022-04-01</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><th></th><th>Corrector</th><th>Uncertainty</th></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Pitch</td><td>2.360 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Roll</td><td>0.040 degrees</td><td>-0.010 degrees</td></tr>
<tr><td>Yaw</td><td>-0.770 degrees</td><td>0.120 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.001 seconds</td></tr>
</table>
</td></tr>
</table>

Vessel	HSL 2808
Echosounder	Kongsberg EM 2040
Date	2022-04-01

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.400 degrees	-0.010 degrees
Roll	0.040 degrees	-0.010 degrees
Yaw	-0.460 degrees	0.120 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	FA 2807
Echosounder	Kongsberg EM 2040
Date	2022-04-01

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.001 seconds
Navigation Time Correction	0.000 seconds	0.001 seconds
Pitch	0.200 degrees	-0.010 degrees
Roll	-0.610 degrees	-0.010 degrees
Yaw	0.260 degrees	0.120 degrees
Pitch Time Correction	0.000 seconds	0.001 seconds
Roll Time Correction	0.000 seconds	0.001 seconds
Yaw Time Correction	0.000 seconds	0.001 seconds
Heave Time Correction	0.000 seconds	0.001 seconds

Vessel	S220		
Echosounder	Kongsberg EM712		
Date	2022-05-06		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.005 seconds
	Navigation Time Correction	0.000 seconds	0.005 seconds
	Pitch	-0.248 degrees	0.040 degrees
	Roll	0.010 degrees	0.040 degrees
	Yaw	0.276 degrees	0.060 degrees
	Pitch Time Correction	0.000 seconds	0.005 seconds
	Roll Time Correction	0.000 seconds	0.005 seconds
	Yaw Time Correction	0.000 seconds	0.005 seconds
	Heave Time Correction	0.000 seconds	0.005 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

Acquisition methods employed are determined based on consideration of sonar system specifications, seafloor topography, water depth, and the capabilities of the acquisition platforms. They are also dictated by the coverage method specified in the Project Instructions for a survey area. For the Kongsberg EM 2040, all multibeam data were acquired in the .all format within the SIS (Seafloor Information System) software. For the Kongsberg EM 712, all multibeam data were acquired in the .kmall format within the SIS (Seafloor Information System) software.Data were monitored in 2D, 3D, and backscatter imagery real-time display windows. A survey template defined the storage location of raw and gridded (survey) data, and the file naming convention for mainscheme (Filename_M.all/.kmall) and crossline (Filename_X.all/.kmall) data. During acquisition, the hydrographers often adjusted parameters of the Kongsberg systems to improve data quality. The following are parameters that are commonly adjusted: the port and starboard beam angle, the force depth fields, ping mode, and yaw stabilization. Settings and specialized filters are found in the Runtime Parameters tear off window within SIS.

During launch acquisition, mainscheme MBES lines are generally run parallel to depth contours with appropriate overlap to ensure the data density requirements for the proper finalized CUBE surfaces are met. For discrete item developments, 200 percent coverage is acquired to ensure least-depth determination by multibeam near-nadir beams. For complete coverage surveys, the HYPACK HYSWEEP realtime coverage display is used in lieu of pre-planned line files. HYSWEEP displays the acquired multibeam swath during acquisition and is monitored to ensure overlap and full bottom coverage. For areas where shoreline verification is not conducted before multibeam acquisition and hazards are suspected to exist, extra caution is taken by “half stepping” shoreward when operating near shore. Half stepping is executed by driving along the edge of real time coverage to prevent the survey vessel from working in un-surveyed waters. Survey launch crews in the field survey to the Navigable Area Limit Line (NALL) line as defined by section 1.3.2 of the HSSD.

Seafloor backscatter data were acquired for all lines during the 2022 field season, logged in the .all files and .kmall.

Navigation and motion data are acquired and monitored in POSView and logged to a POS MV file with a .### extension, starting with .000. Data are logged on a USB flash drive inserted into the PCS and automatically split into 12 MB files. Various position and heading accuracies, as well as satellite constellations, are monitored real-time both in POSView and in Hypack Hysweep to ensure the collection of quality data. It is standard procedure not to log the POS/MV data through UTC midnight on Saturdays. At this time the GPS seconds of the week reset.

Data Processing Methods and Procedures

Following daily acquisition, all data are loaded to an external hard drive connected to the launch acquisition computer. This drive contains a standard file structure created by Charlene, an automated data transfer and batch processing software developed by HSTB and distributed within the PydroXL software suite.

Initial processing is typically completed the same day as acquisition, and employs Charlene to transfer the external hard drive data to the Fairweather's' network and process it to a daily QC product, which is typically a bathymetric surface with data from that acquisition platform. Charlene automates the following tasks between raw data collection and the final daily product:

1. Perform verification of raw data
2. Build a deliverable directory structure
3. Transfer and verify raw data
4. Convert the Kongsberg .all file to CARIS HIPS HDCS format
5. Apply delayed heave from the POS files
6. Generate and apply SBET and SBET RMS files
7. Georeference Data which includes

Apply sound speed correctors
Apply a GPS Tide via a separation model (VDATUM or ERTDM)
Compute the Total Propagated Uncertainty

8. Generate a CARIS CSAR bathymetric surface from the data

Once Charlene has completed, night processors inspect the data in CARIS HIPS to ensure all correctors have been properly applied, and that the final products reflect observed conditions to the standards set by the relevant OCS guidance. Bathymetric surfaces are reviewed to ensure that all data quality problems are identified and resolved if possible, and all submerged features are accurately represented.

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

The field unit’s final deliverable bathymetric surface is a variable resolution (VR) Combined Uncertainty and Bathymetric Estimator (CUBE) surface for complete coverage surveys. The CUBE surface’s resolution, depth range, and parameters follow HSSD section 5.2.2. The bathymetric surfaces are generated following the application of all correctors highlighted above in Section C.1.1.

C.1.4.2 Depth Derivation

Multibeam data were reviewed and analyzed in CARIS HIPS Subset Editor, utilizing the generated CUBE surfaces for directed data editing to reject data that led to fliers in the surface. The surfaces were also used to demonstrate coverage and to check for errors due to tides, sound speed, attitude, and timing.

Vessel heading, attitude, and navigation data were reviewed in HIPS Navigation Editor and Attitude Editor if deemed necessary upon review of surfaces. Where necessary, data spikes (fliers) or gaps in heading, attitude, or navigation data were manually rejected or interpolated for small periods of time. Any editing of this nature is outlined in the Descriptive Report for the particular survey.

Hydrographers may designate soundings if the bathymetric surface fails to represent navigationally significant depths and features. Designated soundings are selected following the criteria in section 5.2.1.2.3 of the HSSD.

C.1.4.3 Surface Computation Algorithm

All VR surfaces are generated via the Ranges estimation method within CARIS HIPS and SIPS. This algorithm grids data based on the resolution requirements for each depth range, adhering to the specifications in the HSSD. The following options are selected for the Ranges Estimation Method:

- Range/Resolution File: NOAA_DepthRanges_ObjectDetection.txt (for object detection surveys) or NOAA_DepthRanges_CompleteCoverage.txt (for complete coverage surveys)

- Range Estimation Method: Percentile

- Input Band: Depth

- Output Vertical Coordinate System: Unknown

- Keep Partial Bins: Checked

- Maximum Grid Size: 128

- Minimum Grid Size: 4

The population method utilized for the generation of the Ranges surfaces was CUBE. The following options were selected for the generation of each surface:

- Disambiguation Method: Density and Locale

- IHO Order: S44 Order 1a

- Display Bias: Highest

- CUBE Configuration: NOAA_VR

The CUBE Configuration utilized comes from the CUBEParams_NOAA_2022.xml file included within the Caris_Support_Files_2022v1. This file contains the parameters necessary to create CUBE surfaces meeting the requirements as stated in the HSSD.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

The Kongsberg EM 2040 system logs backscatter to the .all file concurrently with all multibeam data. The HIC monitors the “Seabed Image” tear-off to ensure adequate backscatter imagery is obtained during survey acquisition. The HIC also documents all Kongsberg system frequency changes to aid in file segregation prior to backscatter processing.

Data Processing Methods and Procedures

Backscatter data are processed with the Fledermaus Geocoder Toolkit (FMGT) software using the subsequent steps:

- A new project was created for each frequency used by each vessel within the sheet. For example, if Launch 2806 acquired data in 200 kHz and 300 kHz, two separate projects must be created.

- The vessel pulse mode correction parameters of each frequency for each vessel were set to create a smoother appearance of the imagery between mosaics created for each project within the sheet. These parameters were based on an analysis performed by ship's personnel of data collected over a calibration line during HSRR. This allowed for the generation of single-frequency mosaics across platforms.

- Lines were imported into FMGT, combining the .all files with the HDCS files created in CARIS, resulting in the generation of GSF files.

- A mosaic in floating point GeoTIFF format was created for each project from the imported GSF files. The backscatter mosaic’s minimum resolution depends on the acquisition frequency, using the equation provided in HTD 2018-3. The minimum resolutions for all systems utilized by the field unit were as follows: 6 meters for 100 kHz, 3 meters for 200 kHz, 2 meters for 300 kHz, and 1.5 meters for 400 kHz.

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

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

Vessel attitude is measured by the Applanix POS MV and recorded in both SIS .all files (for real-time correctors) and POS MV .000 files (for delayed heave data). The POS MV continuously logs data to a USB drive throughout the survey day. A five minute buffer period of POS MV data is acquired preceding and following any sonar data acquisition to permit proper initialization of filters for delayed heave and PPK solutions.

Data Processing Methods and Procedures

Attitude correctors applied after initial CARIS HIPS conversion use the raw POS MV attitude data recorded in the Kongsberg data files (.all). The .000 delayed heave file logged by the POS MV is separately loaded into HIPS, replacing the real-time heave values recorded in the raw data.

This .000 file is then post processed in Applanix POSPac to generate a Smoothed Best Estimate of Trajectory (SBET), adjusting the integrated positioning and inertial measurements with Trimble CenterPoint Real-Time Extended (RTX) differential correctors. Trimble RTX uses a network of globally distributed high-performance GNSS receivers that generate the precise orbit, clock, and observation biases for any location on Earth, eliminating the need to establish local reference stations. Post processed RTX corrections are available an hour after data acquisition. The SBET file is exported from WGS84 to NAD83, and then run through the POSPac AutoQC tool in Pydro to evaluate the quality of the ERS vessel positioning. Any short-term unresolvable errors in the GNSS height and uncertainty time series data are manually replaced with an interpolated signal derived from differential heave, dynamic draft, and water level data. Once this quality assessment has been completed, the SBET and corresponding RMS uncertainty file containing the recomputed vessel navigation and ellipsoidal height are applied to the data in CARIS HIPS.

Once SBETs have been applied to the data, a GPS vertical adjustment is computed in CARIS HIPS, utilizing a vertical Datum Model (VDATUM) supplied by HSTB to reduce the data from the ellipse to MLLW.
The data are then reviewed for consistency, ensuring that no vertical offsets due to artifacts in the SBET or improper application exist.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

HSL sound speed profiles are captured with the SeaBird Electronics SBE19plusV2 CTD. All HSLs have small swing-arm davits with 24-volt electric winches for deploying and recovering the CTD profilers. Sound speed profiles are collected while the launch is at rest.

Sound speed casts are taken at least once every four hours during multibeam survey operations in accordance with section 3.5.1 of the FPM. All platforms collect sound speed casts according to observed variations in the water column and any changes in survey location that would influence sound speed differences in excess of the accepted 2 m/s range in accordance with section 5.2.3.3 of the HSSD. Changes are monitored through the real-time surface sound speed view in Sound Speed Manager (SSM) and the data view in SIS. SSM provides a geographic view of changes in surface sound speed which assists in the targeting of casts for zoning water masses. The CastTime algorithm is also employed in SSM to guide cast frequency. In SIS, the user is warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

Data Processing Methods and Procedures

Sound speed cast processing is performed via the HydrOffice Sound Speed Manager (SSM) application. HSL casts are downloaded from the CTD and converted from their raw binary sensor measurements (.hex) to standard units (.cnv) using a manufacturer supplied calibration file (.xmlcon). These files are then smoothed using 1 meter cosine averaged depth bins and saved to the SSM database. The smoothing eliminates errors near the surface resulting from wave action and engine cooling water outflow. Once the profiles have been loaded and filtered or inspected, they are transmitted by SSM over the network to the Kongsberg HWS for application in SIS. SSM confirms reception, or the hydrographer may inspect the updated file name in the “Runtime Parameters” tear-off upon network errors.

All sound speed casts saved to the SSM database are exported into a .svp file that is readable in CARIS HIPS. Casts are progressively concatenated per sheet, including all casts taken within the sheet limits. This concatenated file is applied to all HDCS data using the “Nearest in distance within time” algorithm, using the time interval suggested by the Hydrographer in Charge during acquisition. This time interval is generally four hours, but may be reduced if necessitated by environmental conditions.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

All HSLs use SVP 71 probes. The SVP probes supply the MBES with real-time values, which applies a median filter and corrects for the flat-faced transducer’s refraction. During acquisition, the HIC adjusts this filter's length to capture variability while suppressing bubble sweep-down errors. HICs monitor the surface sound speed for a > 2 m/s change, which requires a new cast using the methods described in C.5.1.

Data Processing Methods and Procedures

Surface sound speed data are not post-processed.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

The final uncertainty for soundings is calculated within CARIS HIPS using the Compute TPU tool. CARIS HIPS computes the TPU based on the vessel's static and dynamic measurements, project specific tidal referencing, ERS positioning, and sound speed values. The TPU section of the HVF captures fixed estimates of uncertainty. Uncertainty values for the multibeam and positioning systems are compiled from manufacturer specification sheets for each sensor, and from those set forth in Section 4.2.9 of the 2020 FPM. CARIS HIPS also applies a sonar device model for uncertainty values associated with the sounding detections.

Vertical uncertainty is provided in the Project Instructions is associated with the VDatum model supplied.

Sound speed uncertainty is estimated based on cast frequency and distribution, with a typical value of 2 m/s employed unless otherwise specified in the DR. Real-time sonar uncertainties are provided via EM 2040 MBES data, and positioning errors are provided via the Applanix Delayed Heave RMS. Following postprocessing of the real-time vessel motion, recomputed uncertainties of navigation and ellipsoidal height are applied in CARIS HIPS via a Smoothed Best Estimate of Trajectory (SBET) RMS file generated in Applanix POSPac.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		FA 2805, 2806,2807, and 2808	FA_S220_EM712
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*
All Vessels	Real-time sonar uncertainties are provided via EM 2040 MBES data, and positioning errors via Applanix Delayed Heave RMS.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

The composite source file (CSF) in S-57/.000 format provided with the Project Instructions is the primary source for shoreline feature verification. The original project file is imported into CARIS HIPS and SIPS, converted to a .hob file, clipped to the sheet limits for the specific survey, and named H#####_Feature_File.hob to be utilized during field verification. Additionally, all bottom samples to be investigated are provided to the field in the project reference file (PRF). All hob files are re-exported to S-57/.000 format for data submission.

Fairweather personnel conduct limited shoreline verification during periods when the tide is less than 0.5m above Mean Lower-Low Water (MLLW) as directed by section 3.5.5.3 of the FPM. Detached positions (DPs) are acquired and edits to the daily field feature files are recorded on boat sheets. An inshore limit buffer line, defined by the distance seaward from the Mean High Water (MHW) line at the scale of the largest chart in the area, is provided with the Project Instructions. This inshore limit buffer line is used in the shoreline acquisition software and on the boat sheet as a reference, and is utilized as described in section 1.1.2 of the HSSD. The NALL is determined in the field as the farthest offshore of one of the following; the MHW inshore limit buffer specified above, the 3.5-meter depth contour, or the inshore limit of safe navigation as defined by the HSSD. All shoreline features from the CSF seaward of the NALL are verified (including an update to depth and/or position as necessary) or disproved during operations. Features inshore of the NALL are not addressed, and features of an ambiguous nature include remarks for further clarification.

Specifically assigned features may be investigated that are inshore of the NALL in accordance with the associated instructions for a given project area.

Detached positions (DPs) acquired during shoreline verification indicate new features, revisions to source features, or source features not found in the field. They are recorded as targets in HYPACK and on boat sheets.

Data Processing Methods and Procedures

During shoreline verification, field detached positions (DP) are acquired as HYPACK .tgt files. Tidal corrections for new/updated heights on features are applied in PydroXL via the Shoreline Attribution Machine (SHAM) program within Charlene. This program takes the observed time (obstim) and observed depth (obsdept) attributes from the Final Feature File that are populated following field investigation and uses the TCARI grid or ERTDM separation model to perform a tidal correction.

New features and any updates to the composite source shoreline, such as ledges or reefs, are acquired or digitized with S-57 attribution and compiled from the field daily files into the H#####_FFF.hob. Updates to source shoreline features primarily include a change in depth/height, position, or S-57 classification. If the position of a feature changes, the existing feature is deleted and a new feature created in the new location. Any changes to depth/height or S-57 classification are done so as an update to the S-57 object with the inclusion of NOAA's object attributes. The SORIND and SORDAT S-57 attribute fields for new features or modified source features are updated to reflect the information for the associated survey number and date (US,US,graph,H#####). All new or modified features are S-57 attributed as applicable and descriptively attributed as New or Update respectively. All unmodified source features retain their original SORIND and SORDAT values. Assigned features that are addressed but not updated are descriptively attributed as "Retain" and unaddressed assigned features are attributed as "Not Addressed." Short descriptive comments taken from the boat sheets or DP forms are listed under the Remarks field.

For significant features that deserve additional discussion, the Hydrographer may include a recommendation to the cartographer in the Recommendations field, along with the notes and investigation methods provided in the Remarks field. Features that are disproved or that do not adequately portray the shoreline are descriptively attributed as Delete in the H#####_FFF.hob layer. Features with the attribution of Delete retain their original SORIND and SORDAT values and include a recommendation from the Hydrographer along with an informative remark.

Images are named in accordance with the convention set forth in HTD 2018-5. They are included with the survey data and stored in the Multimedia folder with the deliverables. References to the images are comma delimited and listed with the file extension in the "Images" attribute for the specific feature. The H#####_FFF.hob along with CARIS HIPS BASE surface(s) are reviewed to compare MBES coverage and features simultaneously. The current NOAA object catalog is used for all CARIS software for processing and the version is documented in the individual Descriptive Reports, along with any deviations in shoreline processing from those listed above. The final shoreline deliverable is an S-57 (*.000) file included with the processed data.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

HSD-OPS recommends bottom sample sites in the project reference file (PRF). The field unit examines these proposed sample sites and potentially eliminates some based on the actual depths found during survey operations (if deeper than 80 m), or supplements them with good anchorage positions located by the ship. Bottom sample locations may also be adjusted by the field unit to investigate areas of interest as determined through analysis of the backscatter data in an effort to ground truth returns of different intensities.

Field units acquire bottom samples with a Kahlsico Mud Snapper and Torpedo grab sampler, as described in Section A.8.1. This method utilizes a hand held sampler to acquire a fist sized sample of the seafloor. Once brought to the surface, the physical sample analysis classifies the sediment type for S57 attribution classification, with the most prevalent bottom type listed first. Attribution is recorded in the field on a bottom sample form and may also be entered into a CARIS feature layer. The sample site's "Nature of Surface" (NATSUR) is characterized as “unknown” upon the field unit’s failure to obtain a sample after three attempts. Field units return samples after completing analysis.

Data Processing Methods and Procedures

All bottom samples are entered or imported into the Final Feature File as Seabed Area (SBDARE) point features and attributed to match the recorded characteristics. Sheet managers link the sample images to the corresponding S-57 SBDARE attributed feature within the Final Feature File.

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Preliminary data cleaning is performed daily during night processing following acquisition, addressing the most blatant fliers and blowouts. Cleaning is primarily done in Subset Editor, rejecting data that cause fliers in the CUBE grid. Following this gross cleaning, Flier Finder, part of the QC Tools package of HydrOffice, is used to assist the search for spurious soundings. Flier Finder is run iteratively until all remaining flagged fliers are deemed to be valid aspects of the steep slopes and dynamic nature of the seafloor. Additionally, the uncertainty, hypothesis count, hypothesis strength, and node standard deviation child layers of the surface in CARIS HIPS are utilized to identify potential problem areas.

D.1.2 Designated Sounding Selection

In depths less than 20 meters in areas of navigational significance where the bathymetric surface does not adequately depict the depth for the given area, a designated sounding may be selected. Designated soundings are selected in accordance with section 5.2.1.2.3 of the HSSD. Detailed designated sounding searches in Subset Editor are only performed in regions expected to contain variation not captured in the standard grid, or when searching for known features. Generation of higher resolution grids than required for the depth range may be used to guide the search for designated soundings.

D.1.3 Holiday Identification

Pydro's "Holiday Finder" tool scans the CUBE surfaces for any empty grid nodes that are surrounded by populated nodes, and flags holidays dependent on the criteria set by the coverage requirements. All flags are then visually inspected to determine the validity of each holiday, and all confirmed holidays are addressed either by acquiring additional data over the gaps, or explaining the cause and likelihood of hazards within each gap.

D.1.4 Uncertainty Assessment

Pydro’s “Grid QA v.5” function verifies that all surfaces meet HSSD’s uncertainty specifications. This tool plots node percentage histograms, which demonstrate surface compliance with the uncertainty standards set forth in the HSSD.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

As a quality control measure, approximately 4% (for complete coverage surveys) of the linear nautical mile total of mainscheme multibeam lines are run on each survey as crosslines. Crosslines are run in accordance with Section 5.2.4.2 of the HSSD. Following acquisition, a surface containing strictly data from mainscheme lines and a surface containing strictly data from crosslines are generated and analyzed with the Compare Grids tool in Pydro. This tool analyzes the difference between the two grids and outputs a difference surface between the depths, as well as a second surface that contains the fraction of NOAA allowable error represented by that depth difference for each node. Additionally, statistics/distribution summary plots of the difference surface and the fraction of allowable error are generated to provide easily interpretable analyses of the differences between the surfaces.

D.1.5.2 Junctions

Survey managers perform junction analyses between the current survey and all adjacent contemporary surveys. To ensure proper overlap between surveys, approximately one bathymetric swath of overlap is acquired at each junction. Surface based and statistical analysis of the junctions is performed through the Compare Grids tool as described in D.1.5.1.

D.1.5.3 Platform to Platform

Agreement and continuity of data collected between platforms is visually investigated by the survey manager to ensure consistency and highlight any potential biases in the data. To aid in the determination of potential biases, the depth child layer of the surfaces is inspected with an increased vertical exaggeration, generally between five and ten times greater.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Processed backscatter mosaics are inspected in CARIS HIPS to ensure that no data were omitted during processing, and that no errors occurred in mosaic generation.

D.2.2 Contact Selection Methodology

Not applicable.

E. Approval Sheet

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

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives. These data are adequate to supersede charted data in their common areas. This survey is complete and no additional work is required with the exception of deficiencies noted herein.

Approver Name	Approver Title	Date	Signature
CAPT John Lomnicky, NOAA	Chief of Party	01/30/2023	
LT Michael Card, NOAA	Operations Officer	01/30/2023	

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	FA_EM712_2022_Wiring_Diagram.pdf 280x - 2022.pdf
Sound Speed Sensor Calibration	DQA_LOG_Master.pdf
Vessel Offset	2022_2805_Offset_Conversion_Workbook.xlsx 2022_2806_Offset_Conversion_Workbook.xlsx 2022_2807_Offset_Conversion_Workbook.xlsx 2022_2808_Offset_Conversion_Workbook.xlsx 2021_Waterline_measurements.pdf Dynamic_Draft_Table_2019.pdf
Position and Attitude Sensor Calibration	2805_POS_GAMS_Report_2022_Dn108.xls 2806_POS_GAMS_Report_2022_Dn102.xls 2808_POS_GAMS_Report_2022_Dn102.xls 2807_POS_GAMS_Report_2022_Dn096.xls
Echosounder Confidence Check	HSRR_2022_Reference_Surfaces.xlsx
Echosounder Acceptance Trial Results	N/A