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-O392-RA-20
Time Frame:	September - October 2020

LOCALITY

State(s):	Alaska
General Locality:	Approaches to Revillagigedo Channel, Alaska

2020

CHIEF OF PARTY
Samuel F. Greenaway, CDR/NOAA

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Date:

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NOAA Ship *Rainier*
Chief of Party: Samuel F. Greenaway, CDR/NOAA
Year: 2020
Version: 1
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A. System Equipment and Software

A.1 Survey Vessels

A.1.1 NOAA Ship Rainier (WTEF)

Vessel Name	NOAA Ship Rainier (WTEF)	
Hull Number	S221	
Description	Steel hydrographic ship	
Dimensions	*LOA*	70.4 meters
	Beam	12.8 meters
	Max Draft	4.7 meters
Most Recent Full Static Survey	*Date*	2014-04-20
	Performed By	The IMTEC Group, Ltd.
Most Recent Partial Static Survey	*Date*	2015-04-20
	Performed By	NOAA Ship Rainier personnel
Most Recent Partial Offset Verification	*Date*	2016-04-19
	Method	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.

Figure 1: NOAA Ship Rainier (S221) just outside of Whale Pass, Alaska preparing to put launches in the water.

A.1.2 RA2 (WZ2572)

Vessel Name	RA2 (WZ2572)	
Hull Number	2701	
Description	Aluminum hull North River Liberty jet-drive survey launch	
Dimensions	*LOA*	7.62 meters
	Beam	3.05 meters
	Max Draft	0.47 meters

Most Recent Full Static Survey	*Date*	2019-03-05
	Performed By	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch

Figure 2: Rainier survey launch RA2 (2701)

A.1.3 RA3 (WZ2573)

Vessel Name	RA3 (WZ2573)	
Hull Number	2803	
Description	Aluminum hull Jensen survey launch	
Dimensions	*LOA*	8.8 meters
	Beam	3.7 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2009-03-01
	Performed By	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch

Most Recent Partial Static Survey	*Date*	2017-09-13
	Performed By	NOAA Ship Rainier and HSTB Field Support
Most Recent Partial Offset Verification	*Date*	2019-04-22
	Method	Spot check verification measurements were conducted using steel tapes, laser range finders, bubble levels, plum-bobs, and collapsible rulers. Measurements concentrated verification between the POS MV antennae and themselves in addition to adjacent launch benchmarks.

Figure 3: Rainier survey launch RA3 in the ice near Dawes Glacier, Alaska.

A.1.4 RA4 (WZ2574)

Vessel Name	RA4 (WZ2574)	
Hull Number	2801	
Description	Aluminum hull Jensen survey launch	
Dimensions	*LOA*	8.8 meters
	Beam	3.7 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2008-03-31
	Performed By	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
Most Recent Partial Static Survey	*Date*	2017-09-12
	Performed By	NOAA Ship Rainier and HSTB Field Support
Most Recent Partial Offset Verification	*Date*	2019-04-22
	Method	Spot check verification measurements were conducted using steel tapes, laser range finders, bubble levels, plum-bobs, and collapsible rulers. Measurements concentrated verification between the POS MV antennae and themselves in addition to adjacent launch benchmarks.

Figure 4: Rainier survey launch RA4 (2801) under way in Lisiansky Inlet, Alaska

A.1.5 RA5 (WZ2575)

Vessel Name	RA5 (WZ2575)	
Hull Number	2802	
Description	Aluminum hull Jensen survey launch	
Dimensions	*LOA*	8.8 meters
	Beam	3.7 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2008-03-31
	Performed By	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
Most Recent Partial Static Survey	*Date*	2017-09-12
	Performed By	NOAA Ship Rainier and HSTB Field Support

Most Recent Partial Offset Verification	*Date*	2019-04-22
	Method	Spot check verification measurements were conducted using steel tapes, laser range finders, bubble levels, plum-bobs, and collapsible rulers. Measurements concentrated verification between the POS MV antennae and themselves in addition to adjacent launch benchmarks.

Figure 5: Rainier survey launch RA5 (2802) underway in Whale Pass, Alaska.

A.1.6 RA6 (WZ2576)

Vessel Name	RA6 (WZ2576)	
Hull Number	2804	
Description	Aluminum hull Jensen survey launch	
Dimensions	*LOA*	8.8 meters
	Beam	3.7 meters
	Max Draft	1.1 meters
Most Recent Full Static Survey	*Date*	2009-03-01
	Performed By	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
Most Recent Partial Static Survey	*Date*	2017-09-13
	Performed By	NOAA Ship Rainier and HSTB Field Support

Figure 6: Rainier survey launch RA6 (2804) underway in Endicott Arm, Alaska.

A.1.7 RA7

<table>
<tr><td>Vessel Name</td><td colspan="2">RA7</td></tr>
<tr><td>Hull Number</td><td colspan="2">1907</td></tr>
<tr><td>Description</td><td colspan="2">Aluminum hull SeaArk survey skiff</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>5.7 meters</td></tr>
<tr><td>Beam</td><td>2.8 meters</td></tr>
<tr><td>Max Draft</td><td>0.35 meters</td></tr>
</table>

Figure 7: Rainier survey skiff RA7 (1907) getting ready to conduct shoreline verification.

A.1.8 RA9

Vessel Name	RA9	
Hull Number	1906	
Description	Aluminum hull SeaArk survey skiff	
Dimensions	*LOA*	5.8 meters
	Beam	2.6 meters
	Max Draft	0.33 meters

Figure 8: Rainier survey skiff RA9 (1906) getting underway to check a shore station.

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg EM710

S221 (Rainier) is equipped with a hull-mounted Kongsberg EM710 Mark II, which operates at sonar frequencies in the 40 to 100 kHz range. The across-track swath width is up to 5.5 times water depth with a published maximum depth of more than 3000 meters. The along-track beamwidth of Rainier’s configuration is ½° with a receive beam width of 1°. The maximum number of beams is 400, with dynamic focusing employed in the near field. A high density beam processing mode provides up to 400 or 200 soundings per swath by using a limited range window for the detections. The beamspacing may be set to be either equiangular or equidistant. Rainier typically collects 400 beams per ping in equidistant mode. The EM710 was upgraded from a Mark I (70-100 kHz system) to a Mark II (40-100 kHz) during Rainier's dry dock period (winter of 2019/2020), in Vallejo, CA. A representative from Kongsberg Underwater Technology LLC (Lynnwood, WA) performed the upgrade by installing Mark II receiver cards in the EM710 TRU.

The EM710 transmit fan is divided into three sectors to maximize range capability but also to suppress interference from multiples of strong bottom echoes. The sectors are transmitted sequentially within each ping, and use distinct frequencies or waveforms. By default, the transmit fan is electronically stabilized for roll, pitch and yaw but Rainier experience has shown that yaw stabilization often caused a noticeable “step” between the three sectors of the transmit fan. Due to this problem, Rainier typically disables yaw stabilization.

Running the Built-in-Self-Test (BIST) on Rainier’s Kongsberg EM710 has resulted in an intermittent fail on BIST 6, for phase limits on the receive channel. Historic logs of the EM710 BIST tests show an increase in the number of points failing over time; however, following the most recent manual cleaning of the sonar transducer by divers, BIST 6 passed with only 3 out of 128 points failing. No data degradation has been observed to date. Additionally, a representative from Kongsberg (Lynnwood, WA) made a site visit in September of 2019. During this visit, noise and reference surface data was acquired, BIST were taken, and Cypher60 impedance testing was completed. The impedenace testing found three suspect channels in the receive array, and four suspect channels in the transmit array. Kongsberg was not alarmed by the results of the impedence and phase values, and recommended continuing to track overall system health with repetative BIST over time.

Following our field calibration off of the coast of San Francisco, CA in February 2020, we identified an incorrect offset in Kongsberg's SIS Installation Parameters. This offset was unknowningly present over the past several years, but was corrected for in the Caris Vessel Configuration file (HVF). The correct offsets are now entered into SIS, the correction is removed from Caris HVF. All offsets were verified prior to the start of Rainier's Hawaii and Vicinity survey.

Manufacturer	Kongsberg				
Model	EM710				
Inventory	*S221*	*Component*	Processor	Receiver	Transducer
		Model Number	EM710	EM710	EM710
		Serial Number	0356	218	unknown
		Frequency	N/A	N/A	40-100 kHz
		Calibration	N/A	2020-02-13	2020-02-13
		Accuracy Check	N/A	2020-02-16	2020-02-16

Figure 9: Kongsberg EM710 sonar transducer housing on Rainier (S221).

A.2.1.2 Kongsberg EM2040 (07 version)

The Kongsberg EM2040-07 consists of four units, a transmit transducer, a receive transducer, a processing unit, and a workstation. The EM2040 system includes a 0.7 degree receiver and an option of two different transmitters: 0.4 and 0.7 degrees are available. The "07" version of the system in use on all Rainier launches features the transmitter of 0.7 degrees. With roll, pitch and yaw stabilization, the transmit fan is divided into three sectors pinging simultaneously at separate frequencies. The system utilizes nearfield focusing on both transmit and receive. Water column logging is also supported.

The EM2040 has a frequency range of 200-400 kHz. The single transmitter configuration has three standard modes. The 300 kHz mode (max depth 465m, max coverage 640m) is used for normal operation, giving an optimum balance between high resolution, depth capability and tolerance of detrimental factors such as water column sediments. The 200 kHz mode (max depth 600m, max coverage 880m) has the best maximum depth capability. The 400 kHz mode (max depth 300m, max coverage 385m) provides the finest resolution in shallower depths for detailed inspection of features such as wrecks.

Manufacturer	Kongsberg
Model	EM2040 (07 version)

Inventory	Unit	*Component*	Processor	TX transducer	RX transducer
	2801	*Model Number*	EM2040-07	EM2040-07	EM2040-07
	2801	*Serial Number*	40130	244	367
	2801	*Frequency*	N/A	200-400 kHz	200-400 kHz
	2801	*Calibration*	N/A	2020-09-01	2020-09-01
	2801	*Accuracy Check*	N/A	2020-09-01	2020-09-01
	2802	*Model Number*	EM2040-07	EM2040-07	EM2040-07
	2802	*Serial Number*	40129	262	373
	2802	*Frequency*	N/A	200-400 kHz	200-400 kHz
	2802	*Calibration*	N/A	2020-02-05	2020-02-05
	2802	*Accuracy Check*	N/A	2020-02-12	2020-02-12
	2803	*Model Number*	EM2040-07	EM2040-07	EM2040-07
	2803	*Serial Number*	40125	256	392
	2803	*Frequency*	N/A	200-400 kHz	200-400 kHz
	2803	*Calibration*	N/A	2020-02-15	2020-02-15
	2803	*Accuracy Check*	N/A	2020-02-15	2020-02-15
	2804	*Model Number*	EM2040-07	EM2040-07	EM2040-07
	2804	*Serial Number*	40126	257	366
	2804	*Frequency*	N/A	200-400 kHz	200-400 kHz
	2804	*Calibration*	N/A	2020-09-02	2020-09-02
	2804	*Accuracy Check*	N/A	2020-09-02	2020-09-02

Figure 10: The Kongsberg EM2040-07 mounted on survey launch 2803.

A.2.2 Single Beam Echosounders

A.2.2.1 Teledyne Odom Hydrographic Echotrac CV200

The Teledyne Odom Hydrographic Echotrac CV200 hydrographic echo sounder is a rack mountable, dual frequency, single beam echo sounder. The frequency of the high band ranges from 100kHz to 1 MHz while the low band ranges between 3.5kHz and 50kHz. The CV200 has a reported accuracy of 0.01m +/- 0.1% of depth @ 200kHz. The unit is controlled through Teledyne Odom's Windows based software including eChart Display, Control & Logging Software, which is where the frequency is adjusted.

The Echotrac CV200 is paired with the Simrad 50/200 Combi D transducer. The Simrad transducer combines two transducers (50 kHz and 200 kHz) and one temperature sensor in a single housing. It is designed with a streamlined shape for hull mounting on small vessels. The 50 kHz transducer has a longitudinal beam width of 10° and a transverse beam width of 16°. The 200 kHz transducer has a longitudinal and transverse beam width of 7°.

<table>
<tr><td>Manufacturer</td><td colspan="4">Teledyne Odom Hydrographic</td></tr>
<tr><td>Model</td><td colspan="4">Echotrac CV200</td></tr>
<tr><td rowspan="6">Inventory</td><td rowspan="6">2701</td><td>Component</td><td>Topside</td><td>Transducer</td></tr>
<tr><td>Model Number</td><td>CV200</td><td>Simrad 50/200 Combi D</td></tr>
<tr><td>Serial Number</td><td>004152</td><td>unknown</td></tr>
<tr><td>Frequency</td><td>10kHz - 1MHz</td><td>50/200 kHz</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Accuracy Check</td><td>N/A</td><td>N/A</td></tr>
</table>

Figure 11: The Simrad 50/200 Combi D transducer as mounted on 2701 for the Teledyne Odom Hydrographic Echotrac CV200 hydrographic echo sounder.

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 V5

Rainier and all of her launches are outfitted with the Applanix POS MV 320 version 5. The POS MV version 5 offers a number of key new features including:

• Full GNSS support, by using all available GPS and GLONASS satellites.
• Improved Real Time Kinematic (RTK) performance over long baselines using the most advanced Trimble algorithms.
• Removable USB media slot, providing convenient, portable and robust logging of GNSS and inertial observables for processing in POSPac MMS.

The POS MV is a GNSS-aided inertial navigation system, which provides a blended position solution derived from both an Inertial Motion Unit (IMU) and an integrated GNSS receiver. The IMU and GPS receiver are complementary sensors, and data from one are used to filter and constrain errors from the other. This inter-dependence results in higher position accuracy and fewer errors.

Position accuracy is displayed in real time by the POS MV software and is monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables (HSSD) were not exceeded. In addition, the POS MV software displays HDOP and the number of satellites used in position computation. Data acquisition is generally halted when an HDOP of 2.5 is exceeded or the number of satellites available drop below four. However, because positional accuracy can be maintained by the POS MV through short GPS outages with the help of the IMU, data acquisition is not halted during short periods of time when the HDOP and number of satellites used exceeded stated parameters.

In addition to position, the Applanix POS MV also provides accurate navigation and attitude data to correct for the effects of heave, pitch, roll and heading. When using differential correctors, the POS MV generates attitude data in three axes (roll, pitch and heading) to an accuracy of 0.02° or better. Heave measurements supplied by the POS MV maintain an accuracy of 5 cm or 5% of the measured vertical displacement (whichever is greater) for movements that have a period of up to 20 seconds. The Heave Bandwidth filter was configured with a damping coefficient of 0.707. The cutoff period of the high pass filter was determined by estimating the swell period encountered on the survey grounds. These values ranged from 8 seconds (flat water) to 20 seconds (long period ocean swell), with values of 8 or 12 seconds typically. Currently the ship system is set to 20 seconds and the launches are set to 8 seconds.

Applanix “TrueHeave” values are also recorded. The TrueHeave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. When using differential correctors, the POS MV generates heave measurements with an accuracy of 2 cm or 2% of the measured vertical displacement (whichever is greater) for movements that have a period of up to 35 seconds.

Heading accuracy is monitored by the hydrographer in real time. Persistent heading accuracy issues would prompt further investigation of primary and secondary received satellite observations, and heading calibration through GNSS Azimuth Measurement System (GAMS).

Raw GNSS observables are logged on Rainier and all of her survey launches, including navigation, primary GNSS data, IMU data, and other messages listed in section C.4. These data are used to post process POS MV data to produce superior position and attitude data and can be used to produce a Post-Processed Kinematic (PPK) GPS solution. When using PPK methods, the POS MV generates roll and pitch data with an accuracy of 0.008° and heading data with an accuracy of 0.02°. However, PPK attitude is not applied in post processing since this would overwrite timing offsets implemented in SIS Installation Parameters. Horizontal position is accurate to +/- 8 mm + 1 ppm x baseline length while vertical position is accurate to +/- 15 mm + 1 ppm x baseline length.

Manufacturer	Applanix			
Model	POS MV V5			
Inventory	*S221*	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7273	353
		Calibration	2020-08-03	2020-08-03
	2701 (RA2)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	8957	343
		Calibration	N/A	N/A
	2801 (RA4)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7264	4442
		Calibration	N/A	N/A
	2802 (RA5)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7162	4446
		Calibration	2020-02-05	2020-02-05
	2803 (RA3)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7272	4445
		Calibration	2020-02-15	2020-02-15
	2804 (RA6)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7274	4444
		Calibration	N/A	N/A

A.5.1.2 Trimble Pathfinder Pro XRS

Rainier personnel use the Trimble “backpack” GPS system to obtain positions of selected shoreline features. They are also useful in positioning linear features on the shore such as finger piers or roads where the user can simply go ashore and walk the boundary of the object in question while wearing the backpack. The system consists of a Pathfinder Pro XRS, a 12-channel GPS receiver that provides real-time 1-2 meter accuracy with built-in Coast Guard differential beacon reception capability.

The Pathfinder Pro XRS receiver is connected to a Toughbook all-weather laptop computer running CARIS Notebook. Due to both the portable and weather resistant attributes of this setup, it can be used in an open skiff to augment traditional shoreline verification in a survey launch.

Manufacturer	Trimble		
Model	Pathfinder Pro XRS		
Inventory	*Component*	GPS Receiver	GPS Receiver
	Model Number	Pathfinder Pro XRS	Pathfinder Pro XRS
	Serial Number	0224070094	0224070154
	Calibration	N/A	N/A

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

A.5.4.1 Laser Technology Inc. Impulse 200 LR

The Impulse 200 LR (long range) is a hand-held, light weight laser ranging instrument which includes onboard calculation ability for height, horizontal, and vertical distance. The typical max range to a non-reflective target is 500m (1,640ft) with range accuracy of 3-5 centimeters. Two AA batteries supply up to 20 hours of use. Aiming is simplified with a 1X red-dot scope. In addition to measuring the distance to shoreline features, this instrument is also used to measure the waterline of Rainier.

Manufacturer	Laser Technology Inc.	
Model	Impulse 200 LR	
Inventory	*Component*	Hand-held laser
	Model Number	200LR
	Serial Number	108786
	Calibration	N/A

A.5.4.2 Leica DISTO lite5

The Leica DISTO lite5 is a splash and dust proof handheld laser range finder that emits a Class II 0.95mW laser on a wavelength of 620-690nm. Ranges measurable vary from 0.2m up to 200m with the smallest unit displayed 1mm. Measuring accuracy (at 2x standard deviation) is typically ± 3mm, ± 5mm at the instrument's extreme range.

<table>
<tr><td>Manufacturer</td><td colspan="3">Leica</td></tr>
<tr><td>Model</td><td colspan="3">DISTO lite5</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4"></td><td>Component</td><td>Hand-held laser</td></tr>
<tr><td>Model Number</td><td>DISTO lite5</td></tr>
<tr><td>Serial Number</td><td>40300556</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
</table>

A.5.4.3 Velodyne VLP-16

The VLP-16 is a real-time 3D LiDAR (Light Detection And Ranging) sensor that provides high definition 3-dimensional information about the surrounding environment. The laser type used is a class 1 eye safe laser operating at a 903 nm wavelength. The VLP-16 creates 360° 3D images by using 16 laser/detector pairs mounted in a compact housing. The housing rapidly spins to scan the surrounding environment. The lasers fire thousands of times per second, providing a rich, 3D point cloud in real time.

Advanced digital signal processing and waveform analysis provide high accuracy, extended distance sensing, and calibrated reflectivity data. Unique features include: a horizontal field of view of 360°, rotational speed of 5-20 rotations per second (adjustable), vertical field of view of 30°, and returns of up to 100 meters. The sensor offers an angular resolution of 2° (vertical) and 0.1º - 0.4º (horizontal/azimuth) in addition to a typical range accuracy of ~3cm.

VLP-16 units are integrated with the launch HYPACK acquisition systems and are used for determination of the height and position of exposed shoreline features.

<table>
<tr><td>Manufacturer</td><td colspan="3">Velodyne</td></tr>
<tr><td>Model</td><td colspan="3">VLP-16</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">2701</td><td>Component</td><td>LiDAR Puck</td></tr>
<tr><td>Model Number</td><td>VLP-16</td></tr>
<tr><td>Serial Number</td><td>29415368</td></tr>
<tr><td>Calibration</td><td>N/A</td></tr>
</table>

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 MVP200 Moving Vessel Profiler (MVP)

Rainier is equipped with an AML Oceanographic MVP200 Moving Vessel Profiler (MVP). This system consists of a sensor fish, a conductor cable, a computer controlled high speed hydraulic winch, and a cable metering system. In the underway mode, the sensor fish is towed behind the ship and periodically is allowed to free-fall near vertical through the water column recording sound velocity profiles. This enables Rainier to take sound speed casts without stopping the ship. To take deeper SV casts and take full advantage of all the cable on the drum, the ship must come to a stop. While stationary, 600 meter deep sound speed casts may be collected as opposed to a maximum of 235 meters deep when the ship is in typical survey mode and underway at 10 knots.

The actual sensor package contained within the towfish is an Applied Microsystems Micro CTD. The unit consists of a 4-electrode conductivity sensor accurate to +/-0.01 mS/cm with a resolution of 0.001 mS/cm, a temperature (precision aged thermistor) sensor accurate to +/-0.005° C with a resolution of 0.001° C, and a pressure (temperature compensated strain gauge) sensor accurate to +/-0.05% FS (full scale) with a resolution of 0.005% FS. The Micro CTD supplied with the MVP200 is rated at 1000-dBar.

In the past, the MVP200 experienced several failures of the Micro CTD caused by the unprotected conductivity sensor unit protruding from the side of the towfish being sheared off. The likely cause was determined to be loose floating kelp snagging on the delicate conductivity sensor and causing it to break off. In an effort to mitigate this issue, the manufacture was contacted and provided Rainier with stainless steel sensor guards similar to those found on the MVP30.

Manufacturer	AML Oceanographic						
Model	MVP200 Moving Vessel Profiler (MVP)						
Inventory	*S221 Rainier*	*Component*	CTD	CTD	CTD	CTD	CTD
		Model Number	Micro CTD	Micro CTD	Micro CTD	Micro CTD	Micro CTD
		Serial Number	7510 (spare)	8614 (spare)	7761 (spare)	7511 (spare)	8565
		Calibration	2016-04-11	2018-12-13	2016-04-11	2016-04-15	2018-01-24

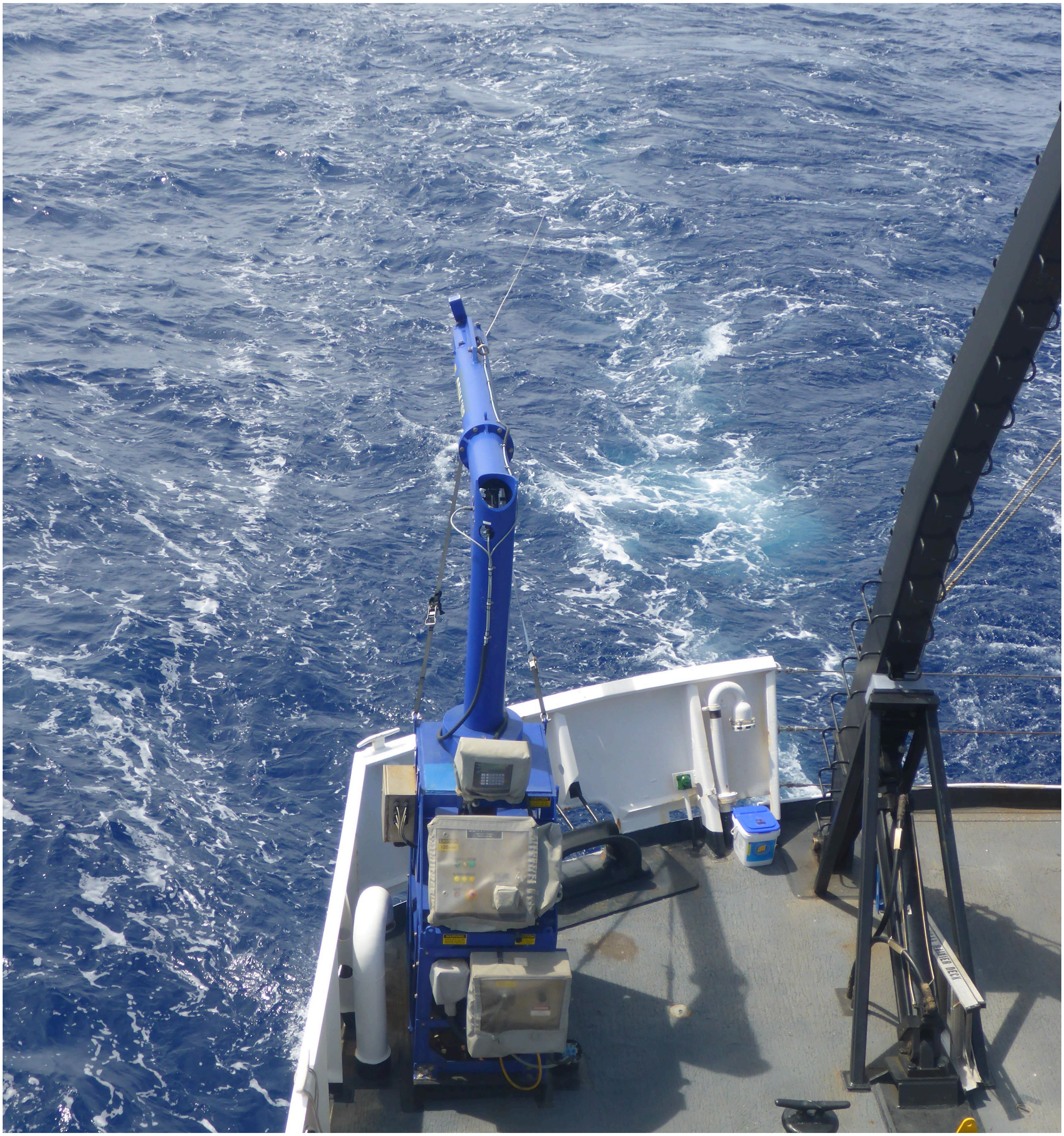

Figure 12: The MVP200 deployed during survey operations off O'ahu, Hawaii

A.6.2 CTD Profilers

A.6.2.1 SEA-BIRD Electronics, INC SBE 19 SEACAT

The SEACAT SBE 19 profiler measures the electrical conductivity and temperature of seawater versus pressure. The aluminum housing allows for use in depths up to 3400 meters (11,150 feet). The sampling rate is set by command to the instrument with a maximum rate of 2 scans per second. Data are temporarily saved on an internal 64 Kbytes of solid-state memory which allows 1.5 hours of recording while sampling at two scans per second. The profiler is self -powered with 6 alkaline batteries which provide up to 48 hours of continuous operation.

The SEACAT embodies sensor elements (Pyrex cell and pressure-protected thermistor) and a Wein-bridge oscillator interface technique using multiplexing. This technique allows a single oscillator to service both temperature and conductivity measurements. The pressure sensor is a Senso-Metrics Series SP-91 strain-gauge sensor. Set-up, check-out, and data extraction are performed without opening the housing via an external computer connected to a bulkhead connector at the base of the profiler with a serial cable.

To ease quick identification of individual SEACAT profilers, Rainier affixed a uniquely colored band of electrical tape around the housing at the top of each profiler. When assigned to a field unit in the plan of the day, the SEACAT profiler is simply referred to by color such as “green” or “black”. All Rainier launches (2801, 2802, 2803, and 2804) are equipped with 24-volt electric winches attached to small swing-arm davits to deploy and recover CTD profilers while the vessel is at rest.

<table>
<tr><td>Manufacturer</td><td colspan="2">SEA-BIRD Electronics, INC</td></tr>
<tr><td>Model</td><td colspan="2">SBE 19 SEACAT</td></tr>
<tr><td rowspan="4">Inventory</td><td>Component</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>SBE 19</td></tr>
<tr><td>Serial Number</td><td>192472 -0281</td></tr>
<tr><td>Calibration</td><td>2020-03-26</td></tr>
</table>

Figure 13: The SEACAT SBE 19 profiler. Note the band of electrical tape around the housing at the top of profiler marking this as the "green" CTD.

A.6.2.2 SEA-BIRD Electronics, INC SBE 19plus SEACAT

The SBE 19plus SEACAT profiler is designed to measure conductivity, temperature, and pressure in marine or fresh-water environments. The plastic housing of the profiler is rated for depths up to 600 meters (1950 feet). The 19plus runs continuously, sampling at four scans per second (4 Hz). Nine D-size alkaline batteries provide 60 hours operation in profiling mode. Eight Mbytes of FLASH RAM records 50 hours of conductivity, temperature, and pressure data while sampling at four scans per second.

To ease quick identification of individual SEACAT profilers, Rainier affixed a uniquely colored band of electrical tape around the housing at the top of each profiler. When assigned to a field unit in the plan of the day, the SEACAT profiler is simply referred to by color such as “green” or “black”.

All Rainier launches (2801, 2802, 2803, and 2804) are equipped with 24-volt electric winches attached to small swing-arm davits to deploy and recover CTD profilers while the vessel is at rest.

Manufacturer	SEA-BIRD Electronics, INC
Model	SBE 19plus SEACAT

Inventory

Component	CTD	CTD	CTD	CTD	CTD	CTD	CTD
Model Number	SBE 19plus	SBE 19plus	SBE 19plus	SBE 19plus	SBE 19plus	SBE 19plus	SBE 19plus
Serial Number	26069-4039 (black)	27151-4114 (yellow)	30319-4306 (blue)	31464-4343 (purple)	19P-7530 (red)	4676 (spare)	4778 (spare)
Calibration	2020-03-26	2020-03-26	2020-03-26	2020-03-26	2020-03-26	2020-03-26	2020-03-26

Figure 14: The SBE 19plus SEACAT profiler. Note the band of electrical tape around the housing at the top of profiler marking this as the "purple" CTD.

A.6.3 Sound Speed Sensors

A.6.3.1 Reson Inc. SVP 70

The SVP 70 is a direct reading sound velocity probe with a sound transmission path of 125mm. The unit's housing is constructed of robust titanium that eases cleaning in environments with high levels of marine growth and is recommended for permanent installations. The SVP 70 is used on all MBES launches (2801, 2802, 2803 & 2804) in addition to Rainier. Since Rainier can only service the SVP 70 during a dry dock, two of these sensors are mounted simultaneously in the event that one fails.

Aboard Rainier, these two sensors are mounted in close proximity to the ship's multibeam transducers and provide real time surface sound speed values for refraction corrections. Yearly calibrations of these SVP 70s are not performed since the instrument can only be removed from the ship during a dry dock. The relative health of these sound speed sensors are monitored whenever the ship is collecting MBES data by comparing live sound speed values to MVP, CTD and/or XBT casts whenever they occur to guarantee correct operation.

Aboard MBES launches, the SVP 70 sensor is mounted in close proximity to each launches' multibeam transducers and provides real time surface sound speed values for refraction corrections.

<table>
<tr><td>Manufacturer</td><td colspan="4">Reson Inc.</td></tr>
<tr><td>Model</td><td colspan="4">SVP 70</td></tr>
<tr><td rowspan="20">Inventory</td><td rowspan="4">S221 Rainier</td><td>Component</td><td>Surface sound speed sensor</td><td>Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td>SVP 70</td><td>SVP 70</td></tr>
<tr><td>Serial Number</td><td>3013020</td><td>4408373</td></tr>
<tr><td>Calibration</td><td>2019-11-19</td><td>2019-12-10</td></tr>
<tr><td rowspan="4">2801</td><td>Component</td><td colspan="2">Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td colspan="2">SVP 70</td></tr>
<tr><td>Serial Number</td><td colspan="2">4517079</td></tr>
<tr><td>Calibration</td><td colspan="2">2018-02-28</td></tr>
<tr><td rowspan="4">2802</td><td>Component</td><td colspan="2">Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td colspan="2">SVP 70</td></tr>
<tr><td>Serial Number</td><td colspan="2">4517077</td></tr>
<tr><td>Calibration</td><td colspan="2">2018-03-02</td></tr>
<tr><td rowspan="4">2803</td><td>Component</td><td colspan="2">Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td colspan="2">SVP 70</td></tr>
<tr><td>Serial Number</td><td colspan="2">3417109</td></tr>
<tr><td>Calibration</td><td colspan="2">2018-03-05</td></tr>
<tr><td rowspan="4">2804</td><td>Component</td><td colspan="2">Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td colspan="2">SVP 70</td></tr>
<tr><td>Serial Number</td><td colspan="2">2817018</td></tr>
<tr><td>Calibration</td><td colspan="2">2018-03-01</td></tr>
</table>

Figure 15: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.

A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
CARIS	HIPS and SIPS (x64)	11.2.4	Processing
CARIS	BASE Editor (x64)	5.3.0	Processing
Applanix	POSPac MMS	8.4 Service Pack 2	Processing
QPS	FM Geocoder Toolbox (FMGT)	7.9.4	Processing
NOAA (HSTP)	PydroXL_19	19.4	Processing
HYPACK, Inc.	Hypack 2018	18.1.8.0	Acquisition
Kongsberg Maritime AS	SIS	4.3.2 build 31	Acquisition
Applanix Corporation	MV-POSView	9.12	Acquisition
ODIM	MVP Controller	2.430	Acquisition

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 AMS, Inc. 15 lb SST Dredge #445.10

The AMS 15 lb SST Dredge is a Ponar type grab sampler, a commonly used sampler that is very versatile for all types of bottom sediments such as sand, gravel and clay. This modified Van Veen type self-tripping sampler features center hinged jaws and a spring loaded trigger pin that releases when the sampler makes impact with the bottom. The sampler's jaws are closed by the scissor action of the lever arms when the sampler is retrieved. The sampling area is 6" x 6".

The sampler is constructed with stainless steel jaws and powder-coated carbon steel lever arms for corrosion resistance. It also includes an underlip attachment that cleans gravel from the jaws that would normally allow lateral loss of sample during retrieval. The top of the stainless steel sampling chamber has been cut with slits and covered with neoprene rubber flaps which allow water to flow through for a controlled descent and to reduce the frontal shock wave that may displace sediment as the dredge contacts the sample surface. This relatively lightweight model (1/8" stainless plate) is easily used from a small boat with nylon cable.

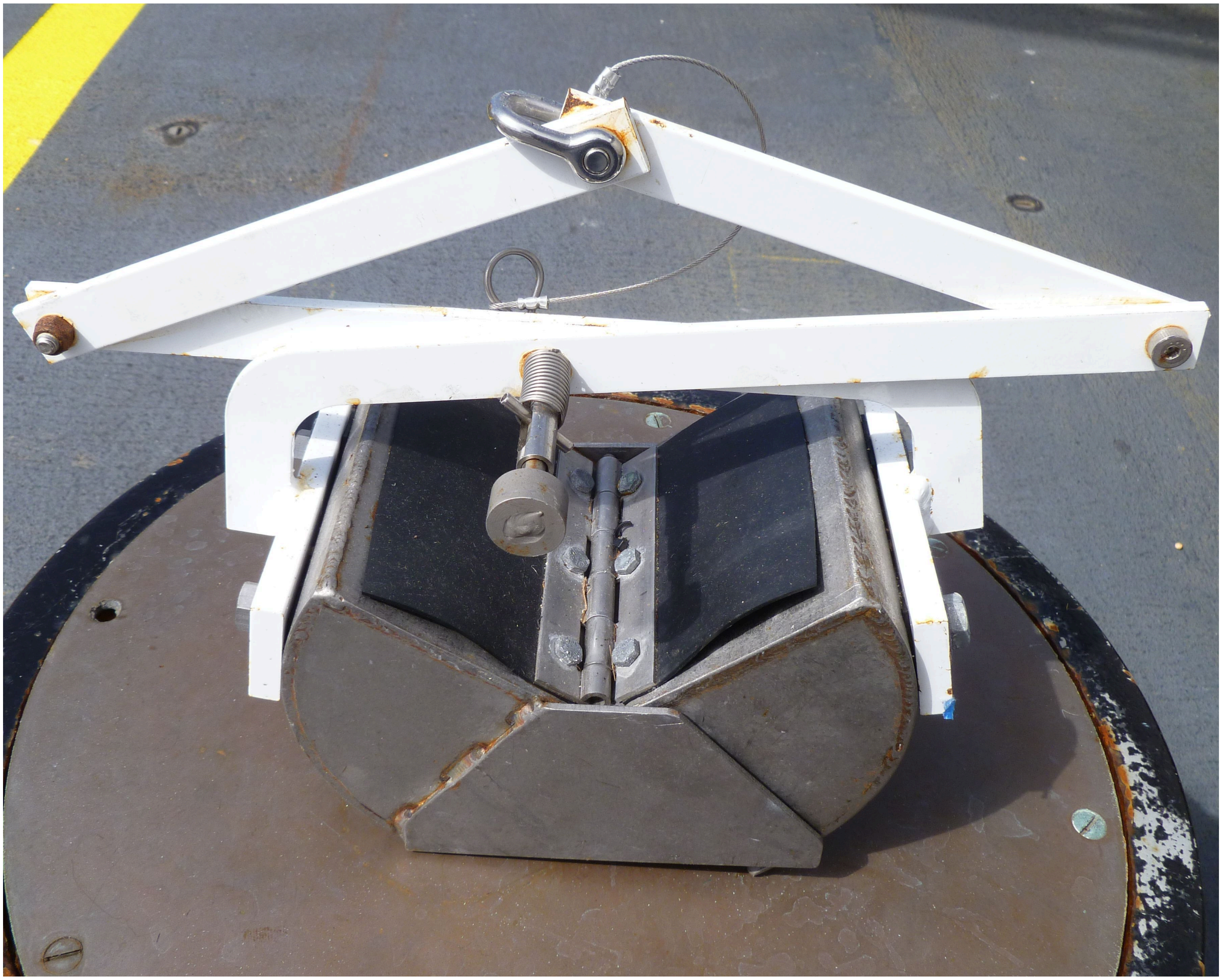

Figure 16: The AMS 15 lb SST Dredge #445.10 Ponar type grab sampler.

A.8.1.2 Unknown Van Veen style grab sampler

This Van Veen Grab Sampler is a hinged clamshell bucket instrument made out of galvanized steel. This sampler is designed to collect unconsolidated sediments up to the size of small pebbles.

While letting the instrument down into the water, the two levers with buckets at their ends are spread like an open scissor. The levers are locked in this position by a hooked metal latch that is designed to drop down and unlock when hitting the seafloor. When the rope is pulled upward again, the two buckets close and grab a sample from the sea floor.

Figure 17: The Van Veen grab sampler configured ready to deploy.

A.8.1.3 Unknown Referred to as the "Nibbler"

The "Nibbler" is a foot-trip model clam shell style bottom sampler. This sampler is designed to collect unconsolidated sediments up to the size of small pebbles. The sampler is fabricated from sturdy bronze and stainless steel materials for trouble-free service in a marine environment.

The "Nibbler" consists of a long threaded post surrounded by a strong compression spring that presses against the jaws at one end and an adjustable screw cap at the upper end. By turning this threaded cap the spring-compression is adjusted, changing the strength at which the jaws close. A shackle is attached through a hole on the top of the post and a line attached. Due to the small of this sampler, it may be deployed either by using a heavy duty fishing pole or by using a handline.

Prior to deployment, the jaws are cocked open by manipulation of a triggering mechanism internal to the jaws. Upon impact with the seafloor the tension is momentarily released on the clam shell jaws, disengaging the internal trigger, and allowing the spring-tensioned jaws to snap shut.

Figure 18: The "Nibbler", a foot-trip clam shell style bottom sampler.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

EM2040

During system integration, HSTP personnel chose the system reference point and reference frame to be centered on and aligned with the EM2040 transmit transducer. While this complicates configuration, it brings the POS MV into the multibeam reference frame. Having the positioning system and the multibeam system in the same reference system eliminates the need for different CARIS HIPS HVF entries depending upon the vertical-control workflow (e.g. ellipsoid vs water-level control).

Full static surveys were not conducted for Rainier's Jensen multibeam launches when the EM2040 multibeam systems replaced the previous outdated SWMB systems in 2017. Due to the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, new offsets were determined by combining the previous NGS spatial relationship survey, the engineering drawings of the echo sounder mount, and a few additional field measurements.

As part of the field measurements, the bolt holes for the sonar transducer mounting plate were measured inside the hull relative to the IMU. With this measurement and the engineering drawing of the mount, the transducer offsets from the attachment hole was calculated. All transducers are mounted in a “forward” convention, with the transmitter cable on the port side, receiver cable output towards the bow.

The offsets between the EM2040 transmit transducer and the POS MV sensors (IMU and antennas) were entered into the POS MV. The patch test values (the residual misalignment between the multibeam and attitude sensor) were also entered into the POS MV IMU to Reference Frame field. SIS contains only the offsets between the transmit transducer and the receiver and the location of the waterline. The GAMS calibration was re-run after the POS MV reference frame was rotated with the patch test values to align the antenna baseline in the new frame.

Because the POS and Kongsberg frame are explicitly collocated and aligned upfront, the CARIS HIPS HVF is relatively simple. All fields contain all zeros with “apply = No” with the exception of the SVP, TPU, Waterline, and Dynamic Draft fields. SVP1 has all zeros, but SVP2 has the same offsets between the transmit transducer and receive transducer as is entered in SIS (X=-0.305, Y=-0.100, Z=-0.016). The waterline is the same as the entry as is in SIS with “apply = No.”

EM710

Similar to the launch configuration, the RP for Rainier’s MBES system is defined as the EM710 transmit transducer phase center and the offset values spread out between the Kongsberg SIS ship file, the POS MV, and the CARIS HVF. In SIS the offsets entered account for the offset between the EM710 transmitter and receiver. In the POS MV the values entered account for offsets between the EM710 transmitter to the IMU along with the EM710 transmitter to the port antenna. Offsets in the CARIS HVF also account for the offset between the EM710 transmitter and receiver but is entered only in SVP 2 so that sound speed files are properly applied (X=0.057, Y=-1.257, Z=-0.001).

Echotrac CV200

For the CV200 SBES in use on 2701 (RA2), the vessel offset values are stored in the CARIS HVF. The POS MV IMU is defined as Reference Point (RP). Since the IMU is the source for all launch heave, pitch, roll, gyro, and navigation values, all of these sensors have X-Y-Z values of 0,0,0. Only Transducer 1 and SVP 1, the sonar unit, requires non-zero offset values entered.

B.1.1.1 Vessel Offset Correctors

Vessel	2701_CV200			
Echosounder	Teledyne Odom Odom Echotrac CV			
Date	2019-03-21			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.271 meters	0.020 meters
		y	-0.575 meters	0.020 meters
		z	0.418 meters	0.020 meters
	Nav to Transducer	*x*	0.271 meters	0.020 meters
		y	-0.575 meters	0.020 meters
		z	0.418 meters	0.020 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	S221_Simrad-EM710_ICE			
Echosounder	Kongsberg Simrad EM710 0.5x1			
Date	2019-04-10			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Nav to Transducer	*x*	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	-0.308 degrees	
		Roll2	-0.308 degrees	
		Roll2	-0.308 degrees	
		Roll2	-0.308 degrees	

Vessel	2801_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2020-09-01

Offsets

Offset		Measurement	Uncertainty
MRU to Transducer	*x*	0.203 meters	0.010 meters
	y	0.136 meters	0.010 meters
	z	0.535 meters	0.010 meters
	x2	-0.102 meters	N/A
	y2	0.036 meters	N/A
	z2	0.519 meters	N/A
Nav to Transducer	*x*	0.203 meters	0.010 meters
	y	0.136 meters	0.010 meters
	z	0.535 meters	0.010 meters
	x2	-0.102 meters	N/A
	y2	0.036 meters	N/A
	z2	0.519 meters	N/A
Transducer Roll	*Roll*	0.000 degrees	
	Roll2	0.000 degrees	
	Roll2	0.000 degrees	

Vessel	2802_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2020-02-05			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.193 meters	0.010 meters
		y	0.137 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.112 meters	N/A
		y2	0.037 meters	N/A
		z2	0.521 meters	N/A
	Nav to Transducer	*x*	0.193 meters	0.010 meters
		y	0.137 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.112 meters	N/A
		y2	0.037 meters	N/A
		z2	0.521 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	2803_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2020-02-25			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.189 meters	0.010 meters
		y	0.135 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.116 meters	N/A
		y2	0.035 meters	N/A
		z2	0.521 meters	N/A
	Nav to Transducer	*x*	0.189 meters	0.010 meters
		y	0.135 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.116 meters	N/A
		y2	0.035 meters	N/A
		z2	0.521 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	
		Roll2	0.000 degrees	

Vessel	2804_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2020-09-01			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.198 meters	0.010 meters
		y	0.094 meters	0.010 meters
		z	0.538 meters	0.010 meters
		x2	-0.107 meters	N/A
		y2	-0.006 meters	N/A
		z2	0.522 meters	N/A
	Nav to Transducer	*x*	0.198 meters	0.010 meters
		y	0.094 meters	0.010 meters
		z	0.538 meters	0.010 meters
		x2	-0.107 meters	N/A
		y2	-0.006 meters	N/A
		z2	0.522 meters	N/A
	Transducer Roll	*Roll*	0.000 degrees	
		Roll2	0.000 degrees	
		Roll2	0.000 degrees	
		Roll2	0.000 degrees	

B.1.2 Layback

No towfish data were collected for the 2020 field season.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

All Rainier survey launches were constructed with integrated benchmarks that were later surveyed by the National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch. For all launches two of these benchmarks are located on the outboard deck, both port and starboard, close to in-line with the IMU.

For all survey launch static draft values are determined using the two benchmarks located on the port and starboard outboard deck. A carpenter level was placed on these benchmarks and held level to the deck while either a steel tape or laser rangefinder was used to measure directly to the surface of the water. At the same time the launch was kept level by observing the POS MV output and shifting personnel in the launch. Three measurements were taken on each benchmark. Both the port and starboard measurements differenced from the corresponding NGS benchmark to produce a waterline value.

These six values were averaged together to produce a final value. Draft uncertainty is determined based on the standard deviation of these six values. Values measured and derived may be found in the "2019_WaterLine_Loading" report attached to this document.

For Rainier, static draft is determined by direct measurement to the physical waterline. Waterline measurements are entered into SIS Installation Parameters for initial visualization in SIS. Ultimately the waterline value entered into the CARIS HVF is utilized in post processing instead of the draft entered into SIS.

For Rainier, multiple measurements (for averaging) are taken from port and starboard benchmarks to the actual waterline of the ship using the Impulse 200 LR handheld laser. These benchmarks, located on the top lip of the hull on "D" deck, were positioned using coordinate measurement data taken on the Rainier February 14 through February 19, 2014. Kongsberg conducted this ship sensor alignment & orthogonal coordinate survey through a subcontract with IMTEC while the ship was in a floating dry dock at Lake Union Drydock Company, Seattle, WA.

B.2.1.1 Static Draft Correctors

Vessel		2701_CV200	S221_Simrad-EM710_ICE	2801_EM2040	2802_EM2040	2803_EM2040	2804_EM2040
Date		2019-03-21	2020-09-06	2019-03-26	2019-03-28	2019-03-26	2019-03-26
Loading		0.030 meters	0.025 meters	0.013 meters	0.013 meters	0.013 meters	0.013 meters
Static Draft	*Measurement*	0.058 meters	-4.718 meters	-0.643 meters	-0.632 meters	-0.642 meters	-0.638 meters
	Uncertainty	0.004 meters	0.021 meters	0.007 meters	0.002 meters	0.006 meters	0.007 meters

B.2.2 Dynamic Draft

The purpose of the dynamic draft and settlement & squat measurements (DDSSM) is to correlate a vessel's speed through the water with the vertical rise/fall of the vessel's Inertial Navigation System (INS) reference point (typically chosen to be coincident with Inertial Measurement Unit, IMU). Since both Rainier and her launches lack a method of accurately logging speed through the water, the GNSS-based speed over ground (SOG) is used as a proxy. Consequently, the presence of currents introduce errors into the DDSSM that must be mitigated by careful planning of data acquisition methods. Ideally, this test would be conducted in an area with no current, chop, or swell.

Historically, Rainier has performed DDSSM using the ellipsoidally-referenced method in Lake Washington, which is free of tidal effects, currents, and significant wave action. After the move to Newport, Oregon, this was no longer an option. Experiments using the ellipsoidally-referenced method in both open waters of the Pacific Ocean and in the Yaquina River with daily currents up to 3 knots produced poor to unusable results. The best results are obtained by timing data acquisition to coincide with slack current but even these values were suspect.

Because of external factors, such as tide, current, wind, bottom depth, and method of measurement; dynamic draft measurements have been observed to vary insignificantly from year to year and between vessels of the same class. Since all launches found aboard the NOAA Ship Rainier and Fairweather are all of the same class (Jensen) with effectively the same hull design and characteristics we use a single dynamic draft table for all launches. By analyzing 27 dynamic draft measurements collected from 2010 to 2015 between eight vessels (2801-2808), a class specific dynamic draft table with statistically robust values was created. All of Rainier's Jensen survey launches use this single dynamic draft table for 2020 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

DDSSM for all four Rainier Jensen launches were determined as described above and applied to these launches for the 2020 field season.

DDSSM for Rainier was determined on May 1, 2013 using the ellipsoidally-referenced method just outside of Birch Bay, Puget Sound, Washington. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water.

DDSSM for 2701 (RA2) was determined on June 15, 2018 using the ellipsoidally-referenced method near the entrance to Tracy Arm, Alaska. The launch ran reciprocal lines at 5 different speeds holding a steady RPM and dropping to idle for a brief time between each change of RPM. The resulting POS file was then processed to produce RMS and SBET files. These two files were then fed into the Pydro macro ProcSBETDynamicDraft.py that applied tides and computed both Speed over Ground (SOG) and ellipsoidal height for any given time. From this, a delta draft vs speed table and curve was generated using a 4th order best fit polynomial.

Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVFs). Survey platforms which mount more than one acquisition system or use sonar systems with multiple frequencies have a separate HVF associated with each individual acquisition method. Each of these HVFs contains sensor offset and dynamic draft correctors that pertain to this single acquisition system. Sensor offset and dynamic draft correctors were applied to bathymetric data in CARIS during post-processing.

B.2.2.1 Dynamic Draft Correctors

Vessel	2701_CV200		S221_Simrad-EM710_ICE		2801_EM2040		2802_EM2040		2803_EM2040		2804_EM2040	
Date	2018-06-13		2014-01-01		2015-05-09		2015-04-13		2015-04-13		2015-04-13	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*	*Speed (m/s)*	*Draft (m)*	*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	0.00	0.00	0.00	0.00	0.00	0.00
	0.50	0.11	0.50	-0.01	0.50	-0.01	0.50	-0.01	0.50	-0.01	0.50	-0.01
	1.00	0.17	1.00	-0.02	1.00	-0.01	1.00	-0.01	1.00	-0.01	1.00	-0.01
	1.50	0.21	1.50	-0.01	1.50	0.00	1.50	0.00	1.50	0.00	1.50	0.00
	2.00	0.22	2.00	0.00	2.00	0.02	2.00	0.02	2.00	0.02	2.00	0.02
	2.50	0.21	2.50	0.01	2.50	0.03	2.50	0.03	2.50	0.03	2.50	0.03
	3.00	0.19	3.00	0.03	3.00	0.05	3.00	0.05	3.00	0.05	3.00	0.05
	3.50	0.16	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05
	4.00	0.13	4.00	0.08	4.00	0.05	4.00	0.05	4.00	0.05	4.00	0.05
	4.50	0.09	4.50	0.10	4.50	0.03	4.50	0.03	4.50	0.03	4.50	0.03
	5.00	0.05	5.00	0.13	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00
	5.50	0.01	5.50	0.15	5.50	-0.05	5.50	-0.05	5.50	-0.05	5.50	-0.05
	6.00	-0.03	6.00	0.17	6.00	-0.10	6.00	-0.10	6.00	-0.10	6.00	-0.10
	7.00	-0.10	6.50	0.19	6.50	-0.14	6.50	-0.14	6.50	-0.14	6.50	-0.14
	8.00	-0.14	7.00	0.21	7.00	-0.20	7.00	-0.20	7.00	-0.20	7.00	-0.20
	9.00	-0.17										
	10.00	-0.18										
	11.00	-0.21										
	12.00	-0.27										
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.08	0.01	0.08	0.01	0.08	0.01	0.08	0.01	0.08	0.01	0.08	0.01

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

EM2040

Patch testing was initially planned to be conducted for all four Jensen launches in San Francisco Bay, CA in February as part of the HSRR. Patch test values are derived for each value after the applicable test using CARIS. These values are then entered into the HVF before performing the next test. Once all tests are completed, the values were transferred to the POS MV, but with the opposite sign to accommodate rotating the IMU relative to the transducer rather than rotating the transducer relative to the IMU.

Once Rainier arrived in Hawaii to be fit out for her planned Marianas project, multibeam transducers and all acquisition equipment were removed from launches 2801 and 2804 in preparation for leaving two survey launches ashore for the field season. Dive boats would have replaced these two launches, but due to the pause in operations following the outbreak of COVID, the project incorporating both dive and survey operations was canceled.

After Rainier was released from COVID lockdown in Hawaii and concluded ship survey work in the Hawaiian Islands, she proceeded to Newport OR to refuel and pick up the rest of the crew. During the transit from Newport to the working grounds in Alaska, multibeam transducers and acquisition equipment were re-installed on launches 2801 and 2804. Patch testing was conducted for these two launches in early September near Whale Pass, Alaska. Patch test values were derived and transferred to the POS MV by the method described in the previous paragraph.

In their final state, CARIS HVF files and SIS attitude parameters for Kongsberg EM2040 multibeam sonar systems have the patch test values set to zero and all patch test values stored in the POS MV. Patch test values may be present in the HVF during Hydrographic System Readiness Review (HSRR) process when the patch test and reference surface are run on the same day. The reference surface can only be analyzed when the data has current patch test values applied. Since the patch test values are determined by a process which requires multiple rounds of processing carried out by different hydrographers to produce meaningful average values and standard deviations, final values may not be determined until days after the patch test and reference surface were collected. The only way to apply patch test values to the reference surface is to create backdated entries in the HVF. Once the final patch test values are determined, they are entered into the POS MV and zeroed out in the HVF. This entire process should take place prior to the collection of any sonar data for use in charting products.

EM710

As part of the upgrade to ice-hardened transducers for Rainier’s EM710 system, Kongsberg service engineers attended the sea acceptance trials. During these trials, Rainier conducted MBES calibration tests for the Kongsberg EM710. In spite of the Kongsberg multibeam system working on multiple frequencies (40-100 kHz), only one patch test is required since the system has only one transducer. The calibration procedure used follows that outlined in section 1.5.5.1 of the 2014 Field Procedures Manual. Timing, pitch and yaw bias was determined using a steep slope. Roll bias was determined using the standard flat bottom method. The patch test was independently processed in CARIS HIPS, SwathEd, SIS, and Simrad Neptune, and the consensus values entered into SIS.

As part of the annual HSRR, Rainier conducted a patch test for the EM710 multibeam system to confirm the values from the 2014 installation remained unchanged. Without zeroing out any values in SIS or the POS MV, the patch test values would be expected to be at or near zero. The patch test results largely bore this out, although the yaw the obtained was larger than expected and entered into the CARIS HVF. We later found an error in our SIS installation parameters that was present for several years. The issue was that the roll and yaw values were switched in the installation parameters, resulting in this additionally required yaw bias. We changed the SIS parameters to the correct values, removed the yaw correction in the Caris HVF, and conducted another patch test to verify our setup was correct. The POS MV values were considered confirmed and left unchanged.

In contrast with previous sonar setups where all system alignments were applied in CARIS by way of the HVF, alignment correctors for the ship between the IMU and the transducer is applied in the POS MV and alignment between the Tx and Rx is applied in the acquisition software (SIS). In addition, over the winter the ship's acquisition system remains mounted rather than being removed for maintenance and safe storage over the winter and re-installed for the field season as occurs on the launches. In light of these factors, the annual determination of alignment correctors for the ship is a verification of existing values rather than a determination of new values required for the launches due to the annual re-installation of the acquisition systems.

Data was converted in CARIS HIPS using the regular HVF file that already has the heave, pitch, roll and timing values set to zero. True heave, water levels, the most recent dynamic draft, and sound velocity profiles were applied and the data merged before cleaning via Subset and Swath Editor. Biases were determined using the CARIS HIPS Calibration tool by at least five individual testers. The multiple values determined for each bias by individual testers were examined by a reviewer, and obvious outliers rejected before an average was determined. This average value was then applied to the bias in question and applied to the data before moving on to the next bias determination. Bias values were determined in the following order: pitch, roll, and finally yaw. To verify no timing biases exist, we used motion time delay from roll timing (HSTB sonar acceptance script), and found no residual latency in our installation with a 14 ms attitude delay set in SIS (Rice and Greenaway, 2014).

Since the alignment correctors should already be accounted for by SIS, the values determined by the patch test are expected to be zero. As long as the patch test values determined are within a standard deviation of zero, the system alignment is determined to be confirmed and no edits are made to the heave, pitch, roll and timing values in the CARIS HVF.

In addition to average values, standard deviation was also determined for each bias. These values were then used to adjust the Timing (s), MRU Roll/Pitch, and MRU Gyro uncertainties under TPU values in the HVF.

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td>2701_CV200</td></tr>
<tr><td>Echosounder</td><td>Teledyne Odom Odom Echotrac CV</td></tr>
<tr><td>Date</td><td>2019-03-21</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>0.00 seconds</td><td>0.01 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.00 seconds</td><td>0.01 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>1.00 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>1.00 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>1.00 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.00 seconds</td><td>0.01 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.00 seconds</td><td>0.01 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.00 seconds</td><td>0.01 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.00 seconds</td><td>0.01 seconds</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Vessel</td><td>S221_Simrad-EM710_ICE</td></tr>
<tr><td>Echosounder</td><td>Kongsberg Simrad EM710 0.5x1</td></tr>
<tr><td>Date</td><td>2020-08-03</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>0.00 seconds</td><td>0.008 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.00 seconds</td><td>0.008 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.144 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.144 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>0.102 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.00 seconds</td><td>0.008 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.00 seconds</td><td>0.008 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.00 seconds</td><td>0.008 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.00 seconds</td><td>0.008 seconds</td></tr>
</table>
</td></tr>
</table>

Date	2020-08-03
Patch Test Values (Transducer 2)	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.008 seconds
Navigation Time Correction	0.00 seconds	0.008 seconds
Pitch	0.00 degrees	0.144 degrees
Roll	0.00 degrees	0.144 degrees
Yaw	0.00 degrees	0.102 degrees
Pitch Time Correction	0.00 seconds	0.008 seconds
Roll Time Correction	0.00 seconds	0.008 seconds
Yaw Time Correction	0.00 seconds	0.008 seconds
Heave Time Correction	0.00 seconds	0.008 seconds

Vessel	2801_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2020-09-02
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.005 seconds
Navigation Time Correction	0.00 seconds	0.005 seconds
Pitch	0.00 degrees	0.196 degrees
Roll	0.00 degrees	0.196 degrees
Yaw	0.00 degrees	0.176 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.00 seconds	0.005 seconds
Yaw Time Correction	0.00 seconds	0.005 seconds
Heave Time Correction	0.00 seconds	0.005 seconds

Date	2020-09-02
Patch Test Values (Transducer 2)	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.005 seconds
Navigation Time Correction	0.00 seconds	0.005 seconds
Pitch	0.00 degrees	0.196 degrees
Roll	0.00 degrees	0.196 degrees
Yaw	0.00 degrees	0.176 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.00 seconds	0.005 seconds
Yaw Time Correction	0.00 seconds	0.005 seconds
Heave Time Correction	0.00 seconds	0.005 seconds

<table>
<tr><td>Vessel</td><td>2802_EM2040</td></tr>
<tr><td>Echosounder</td><td>Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td>2020-02-13</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>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.116 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.116 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>0.395 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.002 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
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<tr><td>Date</td><td>2020-02-13</td></tr>
<tr><td>Patch Test Values (Transducer 2)</td><td><table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.116 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.116 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>0.395 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.002 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Vessel</td><td>2803_EM2040</td></tr>
<tr><td>Echosounder</td><td>Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td>2020-02-16</td></tr>
<tr><td>Patch Test Values</td><td><table>
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<tr><td>Navigation Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.234 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.234 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>0.516 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.002 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.00 seconds</td><td>0.005 seconds</td></tr>
</table></td></tr>
</table>

Date	2020-02-16
Patch Test Values (Transducer 2)	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.005 seconds
Navigation Time Correction	0.00 seconds	0.005 seconds
Pitch	0.00 degrees	0.234 degrees
Roll	0.00 degrees	0.234 degrees
Yaw	0.00 degrees	0.516 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.00 seconds	0.005 seconds
Yaw Time Correction	0.00 seconds	0.005 seconds
Heave Time Correction	0.00 seconds	0.005 seconds

Vessel	2804_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2020-09-03
Patch Test Values	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.005 seconds
Navigation Time Correction	0.00 seconds	0.005 seconds
Pitch	0.00 degrees	0.023 degrees
Roll	0.00 degrees	0.023 degrees
Yaw	0.00 degrees	0.119 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.00 seconds	0.005 seconds
Yaw Time Correction	0.00 seconds	0.005 seconds
Heave Time Correction	0.00 seconds	0.005 seconds

Date	2020-09-03
Patch Test Values (Transducer 2)	

	Corrector	*Uncertainty*
Transducer Time Correction	0.00 seconds	0.005 seconds
Navigation Time Correction	0.00 seconds	0.005 seconds
Pitch	0.00 degrees	0.023 degrees
Roll	0.00 degrees	0.023 degrees
Yaw	0.00 degrees	0.119 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.00 seconds	0.005 seconds
Yaw Time Correction	0.00 seconds	0.005 seconds
Heave Time Correction	0.00 seconds	0.005 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

For both the Rainier's Kongsberg EM710 and the launch Kongsberg EM2040 systems, multibeam data were monitored in real-time with the acquisition software, SIS (Seafloor Information System). Data were displayed using 2-D and 3-D data display windows in the real-time screen display.

For launch acquisition, real-time coverage tools are now exclusively used to assess MBES coverage in lieu of traditional pre-planned line files. During the planning stage, "bite sized" polygons were arranged to cover the entire survey area of each assigned sheet. These polygons were devised to fall within a similar depth range band so that they could be acquired at the proper resolution to find holidays as they occurred in the field. Polygons were also shaped to optimize running with the contours and not against them. Polygons covering deeper areas were planned to be larger than those covering shoaler areas. In general, polygons were sized such that a launch could expect to complete 3 to 5 polygons per day.

Once the polygons were drawn using CARIS BDB or CARIS Notebook, they were exported as S-57 (.000) files or shape files since Hysweep can handle either format. Hysweep displays these polygons over the chart in addition to plotting the MBES swath coverage as it is collected. This display of the real-time swath coverage is based upon the matrix file, a polygon with user defined geographic bounds and resolution set up prior to data collection. The resolution of the matrix is selected to match depth range of the polygon currently being worked on. The launch coxswain uses this matrix display to adjust the line as it is driven so that the swath currently being collected overlaps the grid of previously collected data. By keeping a close eye on the matrix file during initial data collection, any holidays are immediately evident in the field and can easily be filled in. This method of data acquisition saves time in both the pre-planning stage as well as greatly reducing the need for filling holidays during the subsequent rounds of data acquisition. Traditional holiday lines, small polygons, or exported CARIS BASE surface GeoTIFFs may be used to direct data acquisition after post-processing in the event of any holidays found later in the data processing pipeline.

For ship acquisition, a blended solution of line planning and real-time coverage is adopted. At the start of acquisition, a single line is drawn, which the ship navigates via HYPACK. Throughout the line, the survey team notes the swath width and, based on these values, renders the subsequent survey line in such a way to provide ~20% overlap with the previous line. In this way, lines are used to minimize the number of turns and course adjustments required; while the real-time coverage is used to prevent excessive overlap or holidays based on an (ill-informed) a priori line plan.

Data Processing Methods and Procedures

Following acquisition, multibeam sonar data were processed by using the Pydro tool “Charlene”. Charlene is a HSTP developed software utility that automates all of the tasks in-between raw data collection and a final daily product that occur each night. These steps are:

1. Transferring raw data from the Xfer drive to the ship’s network

2. Conversion of “raw” SIS data to the HDCS data format.

3. Import Sensor Data (delayed heave, SBET, RMS)

During typical night processing only delayed heave is configured to be imported by Charlene. SBET and RMS files are typically applied later after they are created and quality checks are complete.

4. Process Data (Georeference Bathymetry), HIPS 11 combines three processes (sound velocity corrections, TPU computations, and vertical datums transformations) in this step.

5. Optionally create a VR depth range or raster surface to check for density issues and holidays using QC tools.

Charlene uses the following options when CUBE surfaces are created:

• Surface Type – CUBE
• IHO S-44 Order – Order 1a
• Include status – check Accepted, Examined and Outstanding
• Disambiguation method - Density & Locale (this method selects the hypothesis that contains the greatest number of soundings and is consistent with neighboring nodes).
• Advanced Configuration – Grid-resolution thresholds are set as a function of depth range as described in the HSSD.

After consultation with the sheet manager, preliminary data cleaning may be performed on “QC” field sheet. Each surface is masked to the appropriate depth range for its resolution using the attribute filter found in the “properties” of the depth layer. The Attribute Filter is enabled by selecting the check box. The filter is set by checking on the button and changing the expression to read “Depth >X AND Depth <Y” where X= min depth for the resolution and Y= max depth for the resolution. E.g. a 2 m resolution surface would get the expression: Depth >18 AND Depth <40.

Preliminary data cleaning is performed daily using “QC” field sheet CUBE surface as a guide for "directed editing". Typically the night processing crew only cleans out the most blatant of fliers and blow-outs, leaving the final cleaning to the sheet manager. Depth, Standard Deviation, Hypothesis Strength and Hypothesis Count models derived from the boat-day surface are viewed with appropriate vertical exaggeration and a variety of sun illumination angles to highlight potential problem areas. Based on this analysis the most appropriate cleaning method is selected as follows:

• Subset Mode is the default tool selected due to its ability to quickly compare large numbers of soundings with adjacent or overlapping data for confirmation or rejection. Subset mode also excels with the assessment of possible features, disagreement between overlapping lines, and crossline comparison. Subset Mode can be used to visually enhance patterns and anomalies in CUBE surfaces.

• Swath Editor is useful for burst noise, multipath, and other "gross fliers" which are specific to a particular line or lines, and most easily removed in this mode. Additionally, when it was felt that the quality of the data was reduced due to environmental conditions such as rough seas or extreme variance in sound velocity, data were filtered on a line by line basis to a lesser swath width to ensure data quality.

• Both modes (but particularly Swath Editor) are used as a training aid to help novices learn how the various sonars operate, and provide feedback to the acquisition process.

With the advent of CUBE-based processing, it has become possible to adjust the final bathymetric surface directly by selecting the correct hypothesis to use. Although this method is available, it standard practice on Rainier to clean soundings in the traditional method until the CUBE algorithm selects the correct hypothesis.

Once all the data from all survey platforms is cleaned based on the depth range to which they will be finalized, the “QC” field sheet CUBE surfaces are examined to ensure bottom coverage and plan additional lines or polygons to fill “holidays”. In addition, the “QC” field sheet is used to compare adjacent lines and crosslines, for systematic errors such as tide or sound velocity errors, sensor error, sonar errors (consistent bad beams), vessel configuration problems, and noise. Any irregular patterns or problems are reported immediately to the FOO and the Survey Manager so that remedies can be found and applied before more data are acquired.

Following directions spelled out in Hydrographic Surveys Technical Directive 2017-2, Variable Resolution (VR) grids are now the final surface deliverable. Due to both a lack of optimization of the “new” VR surfaces in CARIS and older processing machines, Rainier found it difficult to exclusively utilize VR grids as the sole product of night-processing and instead a hybrid approach was used. For initial cleaning single resolution grids are often used while a separate VR surface is analyzed with Pydro QC Tools for density issues and holidays. Only later down the processing pipeline when most of the “bad data” has been cleaned out are VR surface solely used. These VR surfaces are analyzed with QC Tools for fliers during final cleaning in preparation for submission.

Sounding data is added to a master “QC” field sheet encompassing the entire survey. The naming convention of this “QC” sheet naming is Hxxxxx_QC (e.g., H12345_QC).

A coarse 4m resolution “Launch” BASE surface may also be maintained for use in the survey launches during data acquisition. The 4m resolution was selected to maintain smaller, easily transportable GeoTiff files.

• Naming convention is Hxxxxx_4m_DNxxx.
• The surface is created as a single resolution CUBE surface at 4m resolution.
• The CUBE surface is colored using a standardized custom Rainier generated CARIS Colour Range table.
• The color palette selected is intended to aid swift navigation over previously surveyed areas in addition to highlighting shallow areas.

On occasion a finer 1m resolution BASE surface may be created for use in the field when survey launches are expecting to work nearshore. The naming convention and custom CARIS Colour Range table used remain the same as the aforementioned coarse 4m surface.

C.1.2 Single Beam Echosounder

Data Acquisition Methods and Procedures

Launch 2701 (RA2) is the only Rainier survey launch equipped with a single beam echo sounder system (SBES). Currently the primary use of 2701 is to drive parallel to shore as close as safe and practical to the NALL and collect shoreline data by simultaneously collecting Odom SBES data of the seafloor and Velodyne LiDAR data on exposed features. The SBES data are monitored in real-time using the Echotrac control program eChart and recorded by HYPACK 2018 as .RAW files. Adjustable parameters include gain and transmit power.

Data Processing Methods and Procedures

The conversion and application of correctors to single beam data generally mirrors that multibeam data. Surface sound speed is an exception since a surface sound speed sensor is not mounted (or needed) for a single beam system. Single beam is converted into a dedicated project (Hxxxxx_SB) and kept separate from the MBES data. A static surface sound velocity value derived from the CTD cast is used during the import of sensor data and a value of 0.00 is used for the "Surface Sound Velocity" when TPU is computed during the georeference bathymetry step.

Philosophically the cleaning of single beam data must be handled in a different way than multibeam. A BASE surface relies on the number and density of soundings to cancel out the effect of fliers when creating a surface. However, single beam data is often collected in a single line inshore of any MBES coverage. Because this lone line lacks both numbers and density of soundings, any single errant sounding will cause an error in the BASE surface. Single beam must be cleaned to remove every single flier. This is accomplished using the CARIS Single Beam Editor, which allows the user to scroll a line of single beam in profile view and reject soundings as necessary.

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

Although the 2020 HSSD still contains provisions for single-resolution deliverables, Hydrographic Surveys Technical Directive 2017-2 expressed the desire that all NOAA field units should use variable resolution surfaces to the greatest extent possible. Rainier submitted VR surfaces as the deliverable for all 2020 surveys.

For variable-resolution deliverables, the hydrographer creates two surfaces. First is a single surface for the entire hydrographic survey and second is a finalized version of this single surface with the option to honor designated soundings selected. VR surfaces submitted adhere to the following naming convention and use ‘VR’ for the ‘units of resolution:

<Survey Registry Number>_<Sounding Type>_<Units of Resolution>_<Vertical Datum>

Although CARIS provides several options for the creation of VR surfaces, only surfaces using depth-based methods (with prescribed grid-resolution thresholds) or density-based estimation methods (using the Calder-Rice algorithm) are approved. In the case of a depth-based surface, object detection coverage and complete coverage surfaces each have a separate set of approved grid-resolution thresholds.

Although Rainier has experimented with both depth-based and density-based VR surfaces, depth-based surfaces became the preferred method and all VR surfaces submitted for the 2020 field season are of the depth-based variety. It has been Rainier’s observations that a Calder-Rice density-based surface is ~7 times larger than a depth ranges surface covering the same area. This is likely because our sounding density and the resulting resolution of our VR surfaces is much higher than raster surfaces. Depth-based surfaces also appear superior in terms of processing time and ease of use in CARIS.

C.1.4.2 Depth Derivation

Final depth generation in the form of a scale dependent dataset of individual soundings created as the submission product has not been a part of Rainier's processing pipeline ever since CUBE surfaces became the final deliverable.

C.1.4.3 Surface Computation Algorithm

VR surfaces created aboard Rainier adhere to a set of recommended estimation parameters and mandatory population method parameters as documented in 2020 HSSD. Estimation method parameters for Depth-Based CARIS VR Surfaces deal with Range/Resolution values in addition to maximum and minimum grid size. Estimation method parameters for Density-Based CARIS VR Surfaces deal with estimation method (Calder-Rice Density is required), finest cell resolution, in addition to maximum and minimum grid size. Population method parameters for all CARIS VR surfaces deals with horizontal and vertical uncertainty calculation methods, IHO order, and disambiguation method for a given surface in addition to the CUBE configuration parameters values.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Backscatter data are collected by default with the EM710 on Rainier and the EM2040s on her launches.

Data Processing Methods and Procedures

Prior to the 2018 field season HSD issued a Technical Directive that tasked NOAA field units to create and submit processed multibeam acoustic backscatter data using QPS' Fledermaus Geocoder Tool Box (FMGT) software. Since current sonar systems are generally not calibrated, it is inadvisable to mosaic together backscatter from different vessels without explicitly accounting for the relative calibration differences between the systems. To this end, an inter-vessel backscatter calibration test was devised. A single line roughly 200 – 300 meters in length in an area with a flat, consistent surface, free of metal or debris was selected. For each launch the line was run in both directions at survey speed (8 – 10 kts), at every frequency (200, 300, 400 kHz), using every pulse length (SP, LP, FM) for a total of 16 lines per vessel (400 kHz does not have an FM pulse length). By comparing the backscatter across the swath over a flat and consistent seafloor, the backscatter offsets as a function of angle can be determined. Acquiring data on the calibration line in both directions helps to counter the impact of environmental noise.

Relative calibration offsets for each vessel is determined by using commercial software (QPS FMGT) to created mosaics of each survey line. A cross- correlation analysis of the mosaic histograms reveals distinct decibel differences for each vessel, frequency, and pulse length. These offsets values are then used to normalize between common acquisition modes in post-processing, allowing for a more visually consistent mosaic and consistent backscatter data across multiple platforms. In 2019, the backscatter range head bias values (in dB) were determined off ship by HSTB Field Support Liaison, Pacific. All the differences were within 0.3 dB of each other, well within the 0.5 dB tolerance range. Given that the range of the correctors was so small, the field was advised that there was no need to go back and re-process backscatter with the new values. The new values were used going forward and continue to be used for the 2020 field season.

Rainier processes multibeam backscatter to create GSF files and generate backscatter mosaics using QPS FMGT software. The Generic Sensor Files (GSF) created by FMGT contains the backscatter data from Kongsberg .ALL raw data combined with the processed bathymetry located in the HDCS files. Rainier processed and submitted GSF files and backscatter mosaics (one mosaic per frequency for each survey sheet) as part of the regular data submission package.

Following acquisition, backscatter data is processed by using the program FM Geocoder Toolbox (FMGT) and following these steps:

1) A new project is created for each sheet and each vessel and each sonar frequency. Thus one sheet can have multiple projects, one (or more) for each launch and possibly one more for the Rainier.

2) Vessel parameters are set. Vessel parameters allow the hydrographer to set configurations for each launch, frequency, and pulse length, in order calibrate slight differences in decibel levels. This results in a smoother, less patchwork appearance of backscatter mosaics between each launch and frequency/pulse length. Parameter values may be determined by running a calibration line in the same direction with each possible combination of vessel, frequency, and pulse length. Rainier collects backscatter calibration yearly as part of the HSRR.

3) Utilizing inter-boat intensity offsets, lines are combined into single-frequency, multi-boat mosaics. Therefore, if multiple boats had worked in both 200kHz and 300kHz on a single sheet, 2 mosaics are created; one for each frequency.

4) When creating a mosaic for submission, any crosslines not needed in the mosaic are deselected. Export type is set as grayscale GeoTIFF. Initial guidance at the beginning of the field season recommended no more than 35 MB per mosaic in an attempt to keep the file sizes low to allow for easier distribution through the website and other public forums. Multibeam backscatter mosaics follow the naming convention as described in the 2020 HSSD; <Survey registry number>_<Sounding Type>_<Units of resolution>_<vessel>_<frequency>_<xofx> where sounding type is ‘MBAB’ for multibeam echo ounder acoustic backscatter.

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

Data Acquisition Methods and Procedures

The POS MV are optionally configured to receive correctors from the Wide Area Augmentation System (WAAS). The WAAS is a Satellite Based Augmentation System (SBAS) for North America, developed by the Federal Aviation Administration and the Department of Transportation as an aid to air navigation. Usable by any WAAS-enabled GPS receiver, WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite.

WAAS consists of multiple widely-spaced Wide Area Reference Stations (WRS) sites that monitor GPS satellite data. The WRS locations are precisely surveyed so that any errors in the received GPS signals can be detected. Two master stations, located on either coast, collect data from the reference stations via a terrestrial communications network and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through geostationary satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal.

The WAAS specification requires it to provide a position accuracy of 7.6 meters (25 ft) or better (for both horizontal and vertical measurements), at least 95% of the time. Actual performance measurements of the system at specific locations have shown it typically provides better than 1.0 meter horizontally and 1.5 meters vertically throughout most of the contiguous United States and large parts of Canada and Alaska. In more remote regions of Alaska, values range could be slightly higher.

All POS MV systems in use on Rainier and her survey launches are configured to receive WAAS correctors.

Data Processing Methods and Procedures

All WAAS are applied in real time, no post-processing of individual DGPS correctors occurs in Rainier's processing pipeline.

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

All real time position and attitude data are acquired using POSView and post processed using POSPac MMS.

POS MV .000 files are collected by Rainer daily, beginning at least five minutes before the collection of bathymetric data and ending at least five minutes after the conclusion of bathymetric data collection. While conducting 24 hours operations, the POS file is usually broken up into 12 hour pieces to facilitate processing and prevent potential data loss. Logging is started by opening the MV-POSView window and selecting “Ethernet Realtime…” from the Logging menu. In the Ethernet Realtime Output Control window only the following message groups are selected:

For 2701; 3, 7, 10, 20, 102, 111, 112 and 113

For Rainier & MBES launches; 1-5, 9, 10, 99, 110, 112, 10001, 10007, 10008, 10009, 10011 and 10012

The Output Control rate is also set to ‘50Hz’.

Rainier only breaks POS logging at the end of the GPS week (UTC midnight on Saturday) where it is important to not log through UTC midnight. If UTC midnight occurs on any other day of the week, MBES logging is continued until where the record may be broken. Logging POS data for 24 hours a day, and automatically creating a new file every 10 minutes, allows for uninterupted operations. POS MV .000 files corresponding with MBES .all files are then applied in post-processing.

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

Rainier utilizes post processed methods for the horizontal positioning of bathymetric data. The exact method selected is based upon the availability, or lack thereof, of Continually Operating Reference Stations (CORS) near the project area. The four methods available in order of preference are 1) PP-RTX, 2) Smart Base, 3) Single Base, and finally 4) Precise Point Positioning (PPP). For all 2020 projects, Post-Processed Real Time Extended (PP-RTX) was exclusively used to post-process positioning data.

PP-RTX:

Post-Processed Real Time Extended (PP-RTX) is the Trimble CenterPoint RTX positioning solution which combines the methodology of PPP with advanced ambiguity resolution technology to produce cm level accuracies without the need for local reference stations. PP-RTX is used when CORS stations are unavailable and a shore-side reference station would be difficult or impossible to install due to topography, distance from shore, or land use restrictions. RTX positioning has been shown to produce excellent results and is on its way to supplanting Smart Base and Single Base as the preferred processing method.

Smoothed Best Estimate of Trajectory (SBET) files and associated Root Mean Square (RMS) files are calculated using the Applanix Position and Orientation System Post-Processing Package Mobile Mapping Suite (POSPac MMS) software. All SBET/RMS files are created in POSPac MMS using the “Post Processed Real Time Extended” (PP-RTX) aided-inertial processing mode that uses both terrestrial based reference station data combined with wide-area coverage GNSS satellite corrections to generate precise orbit, clock, and observation biases for satellites on a global scale. These corrections are accessed by POSPac MMS 8.1 via internet access to a Trimble network to provide centimeter level positioning corrections which are then applied by RTX to ship and survey launch POS files. No locally installed GPS base stations or CORS station data are used to generate PP-RTX mode SBET/RMS files.

SmartBase:

SmartBase is the preferred method when a minimum of four (six recommended) CORS stations are available for selection near the project area. Accuracies of 3-10 cm are achievable utilizing SmartBase with base-line separations of less than 30 km, as long as the maximum distance from the rover to the nearest reference station in the network is no more than 70 km.

Applanix POSPac software is used to produce a Smoothed Best Estimate of Trajectory (SBET) file. The SBET file consists of GPS position and attitude data corrected and integrated with inertial measurements and reference station correctors. The SBET is created using the Applanix proprietary “SmartBase” algorithm, which generates a Virtual Reference Station (VRS) on site from a network of established reference stations surrounding the project area, generally the Continually Operating Reference Station (CORS) network. Reference station data is downloaded with the POSPac MMS download tool and usually available within 24 hours. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data. For further details on the CORS network stations utilized in addition to processing methodology, refer to the HVCR of the appropriate project.

Single Base:

Due to the dearth of permanent GPS stations installed in the remote regions of Alaska a Smart Base solution utilizing multiple base stations is often not practicable. Single Base is the preferred method when there are not enough CORS stations to form a SmartBase network or when no CORS stations are available and Rainier personnel must establish a GPS base station. In a short baseline situation with a maximum baseline of 20-30 km to the control station, an optimal horizontal accuracy of <10 cm should be achieved.

The Single Base solution of processing SBETs requires the input of attitude data acquired by the POS MV in addition to simultaneously collected base station data. Vessel kinematic data is post-processed using Applanix POSPac processing software, POSGNSS processing software and Single Base processing methods. These SBET navigation and attitude files are applied to all lines in CARIS and supersede initial positioning and attitude data. For further details on the CORS station(s) and/or Rainier installed GPS base station(s) utilized in addition to processing methodology, refer to the HVCR of the appropriate project.

Precise Point Positioning:

Precise Point Positioning (PPP) is used as a last resort when Smart Base or Single Base is not available. This occurs when Rainier conducts survey operations far enough offshore that it is physically impossible to install a shore base station within the recommended 20km radius. Precise Point Positioning may also be used to cover data gaps and/or outages in data from a CORS station or a Rainier installed base station. When PPP is chosen, an optimal vertical accuracy of 10-50 cm should be achieved.

PP-RTX Processing Methodology:

1) Open POSPac MMS 8.4.x or higher.

2) Create a New Project by clicking New Project on the Project tab.

3) Open the .000 POS file found in the appropriate raw data folder and wait for the
to download.

4) Click on “Trimble PP-RTX” button to generate PP-RTX.

5) Click the Gold Star “GNSS-Inertial Processor” button, verify the processing mode is set to In-Fusion PP-RTX, and click the Fast Forward icon to perform all processing.

6) Click Display Plots and look for spikes or use the AutoQC tool for POSPac SBET Quality Control.

7) Once SBET quality is confirmed to be of sufficient quality to proceed, export the project with a File Format of “Custom Smooth Bet”. This will export a custom SBET in NAD83.

8) Copy the SBET and RMS files to the appropriate folder on the processed sheet directory. Rename the export_ YYYY_DDD_VSSL_A.out file to the following format: YYYY_DDD_VSSL_A _SBET.out and the smrmsg_ YYYY_DDD_VSSL_A.out file to the following format: YYYY_DDD_VSSL_A _RMS.out.

Single Baseline and SmartBase processing Methodology:

POSPac .000 and base station data processing conforms to the Ellipsoidally Referenced Surveys Standard Operating Procedure document in the Appendix IV of the FPM. By post processing the POSPac .000, GNSS and base station data, POSPac creates SBET (smoothed best estimate trajectory) files which are used by CARIS along with the corresponding POSPac .000 file to improve the data collected. Applying SBETs in CARIS HIPS increase the accuracies of attitude and navigation related data. Currently it is the responsibility of the HorCon project manager and the sheet manager to work together applying SBETs to the survey after post acquisition tasks are complete.

POSPac has two options for handling shore stations, Single Baseline and SmartBase processing. SmartBase processing is the preferred method but Rainier must often install their own base station and use the single base station method due to the dearth of CORS stations in Alaska.

For the single base station method, the primary-reference baseline separation must be less than 20 km at the start and end of the mission and can occasionally grow to 100 km during the mission. For the SmartBase method, an optimal network consists of six to eight reference stations evenly distributed around the surveyed area and separated by 50 to 70 km. A minimum of four stations are required for Applanix SmartBase processing.

Initial base station processing requires:

• Processing RAW GPS base station data – When geographically possible, raw GPS data is downloaded daily from shore stations as (.T01/.T02) files. These files are converted into RINEX format using Trimble utility program “Convert to RINEX – TBC utility” v2.1.1.0. Three files are produced, files .YYg, .YYn, and .YYo.

• Obtaining Base Station OPUS Solution -- After creating RINEX files from the base station receiver raw file, the .YYo file is then submitted to OPUS in order to get a precise position solution. If bandwidth is an issue, as it usually is aboard the ship, the RINEX file may need to be decimated and zipped to get the file size smaller and achieve a reasonable upload time. A 3mb file usually takes about 3-5 minutes to upload on the ship's Vsat.

• OPUS reference frame and format -- Once the RINEX file size is reasonable (under 7mb), go to the OPUS website at: http://www.ngs.noaa.gov/OPUS. At the OPUS site the user is given the option to choose the new IGS08 reference frame or the old ITRF00 reference frame. Until further testing and verification is done, Rainier continues to use the old ITRF00 reference frame. For Solution Formats, the extended solution + XML (DRAFT) is selected. Once processed, a NGS OPUS solution report is produced in .txt format. It is in this report that the WGS84 coordinates of the base station which are later entered into POSPac are found.

Single Base Station Processing:

1) Open Applanix POSPac™ Mobile Mapping Suite and set up the project

2) Load the Applanix .000 file (recorded on the launch)

3) Load the satellite data logged by the base station (the .YYo file that corresponds to the day number being processed).

4) Once the coordinate manager window opens, the true ITRF coordinates from the OPUS report is input. The same ITRF coordinates are used throughout the project and are checked against "new" OPUS solutions to maintain consistency.

5) Both the SBET (in ITRF format) and smrmsg error data files are created.

Smart Base Processing:

1) Open Applanix POSPac™ Mobile Mapping Suite and set up the project

2) Load the Applanix .000 file (recorded on the launch)

3) Select the "Find Base Stations" option which will generate a list of nearby CORS stations and then click on the "Smart Select" button.

4) POSPac will need the Internet to access and download the base station data it finds as the best option to import. It will need a minimum of 4 stations as well as adequate ephemeris data to continue. This process is done automatically.

5) Once the base stations and ephemeris data have been downloaded, the Raw Data Check-In window will appear automatically, click OK. Once you click OK, POSPac will create a triangulated network of all the base stations it has chosen for processing.

6) Next run the SmartBase Quality Check. POSPac will run the quality check to see if the data downloaded is good enough for processing and generate a Results Summary. If the data is inferior, it will recommend to Re-run the SmartBase Quality Check processor or that there is not enough adequate data to continue.

7) Due to the remote locations Rainier surveys, sometimes there is not an optimal amount of data available. Occasionally you have to override the system and see if the SBET generated is up to spec. This is done by running the Applanix SmartBase processor.

8) Once the Applanix SmartBase processor has finished, the outline of the triangulated network will be highlighted in yellow. This means that you are ready for processing and that the appropriate base stations have been designated and set.

• Batch Processing -- Batch processing allows processing of multiple POS MV .000 files from multiple vessels on a once per day per survey sheet basis.

• POSPac SBET Quality Control -- Once the POSPac project has completed processing successfully, quality control of the SBETs (Smoothed Best Estimated Trajectories) is performed.

• Exporting Custom SBET -- Once the QC is complete and the processing log updated, the next step is to export a custom SBET in NAD83.

For both a Single Base or Smart Base solution, SBETs are applied in CARIS by loading both the SBET files and error data files in smrmsg format. For every SBET file generated during single base station processing there is an associated smrmsg file.

1) Process --> Load Attitude/Navigation data… Load the WGS84 SBET files. Import data for Navigation, Gyro, Pitch, Roll, and GPS Height are all selected for survey launches. Only Navigation and GPS Height are selected for the ship.

2) Process --> Load Error data… Load the smrmsg error data file. Import data for Position RMS, Roll RMS, Pitch RMS, and Gyro RMS are selected for survey launches. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values. Only Position RMS is selected for the ship.

Precise Point Positioning (PPP) Processing Methodology:

In the event that no base station falls within the 20km limit as is often the case with offshore sheets, and a Precise Point Positioning (PPP) solution utilizing precise ephemeris data is used, SBET and RMS are loaded a follows.

1) Process --> Load Attitude/Navigation data… Load the custom SBET files (WGS84). Import data for Navigation and GPS Height are selected for survey launches and the ship.

2) Process --> Load Error data… Load the smrmsg error data file. Import data for just the Position RMS, is selected for survey launches and the ship. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values for the launches.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Rainier and her launches use Sea-Bird SEACAT conductivity, temperature, and depth profilers (CTD) to acquire sound speed data. Rainier may also use the Rolls-Royce Moving Vessel Profiler (MVP200) to acquire sound speed data.

The Sea-Bird SEACAT conductivity, temperature, and depth profiler (CTD):

All of Rainier's Jensen survey launches (2801, 2802, 2803, and 2804) are equipped with 24-volt electric winches attached to small swing-arm davits. These davits are used to deploy and recover Sea-Bird SEACAT profilers while the vessel is at rest. The rate at which the spool deploys line may be adjusted with friction washers controlled by a knob or T-handle located on the side of the winch spool. Rainier utilizes her oceanographic winch when collecting Sea-Bird SEACAT profiles.

Casts are conducted at least every 4 hours to align with application procedures in HIPS and SIPS. Casts were also conducted when moving to a different survey area, or when conditions evolve (such as a change in weather, tide, or current), so as to warrant additional sound velocity profiles. The launch crew also monitors the real-time display of the Reson SVP 70 for changes of 2 m/s or greater in the surface sound velocity indicative of the need for a new cast.

Sound Speed Manager software is used for both setting up and processing data from Sea-Bird SEACAT instruments. Prior to deployment the SEACAT voltage is checked. The SBE 19plus should have a minimum of 9.5 volts and the SBE 19 should have a minimum of 7 volts. In the event of lower voltage readings, the instrument batteries are changed.

The site selected for a CTD cast should be in the deepest portion of the area expected to be surveyed within four hours and that can provide a representative profile. Before the instrument is placed in the water, the Hydrographer must ensure that the plastic tube covering the sensors has been removed.

When conducting SEACAT casts with the SBE 19, the 3-2-1 rule of thumb is followed. The instrument should be turned on and allowed to sit on deck for 3 minutes while the sensors settle and form baseline. The instrument is then set to soak just below the surface for 2 minutes. Finally the instrument is lowered at a rate of 1 meter/second.

When conducting SEACAT casts with the SBE 19plus, the instrument should be lowered and held just below the water's surface for about 1 minute to allow air to escape the salinity cell. After soaking the instrument, it should be lowered at a rate of 1 meter/second through the water column. In areas where lenses of fresh water or other complex sound speed variation near the surface are suspected, the instrument should be lowered slowly (in some cases, much less than 1 meter/second) through the first 5-10 meters of water in order to accurately sample the sound speed. After this initial decent, the instrument should proceed to drop at a rate of 1 meter/second.

The Rolls-Royce Moving Vessel Profiler (MVP200):

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a fish containing a sound speed sensor by free fall. The fish is towed behind the survey vessel in a ready position that is marked by messengers attached to the tow cable. Ideally at survey speeds the fish is “flying” just above the depth of the sonar transducers. The specified depth deployed is selected by specifying a distance off the bottom (typically 10 meters). Once at the depth limit, the winch freefall is automatically stopped and the drag forces on the fish cause it to rise toward the surface due to the ship's forward motion. The cable slack is then pulled in by the winch back to the towing position.

In the event of a particularly deep survey area or prior to the entire survey system being brought on-line, the MVP fish can be manually deployed while the ship is at rest using the hand-operated control box located on the winch. This method ensures that the maximum possible depth is obtained since the cable is deployed vertically. If necessary, during processing of later casts, the deep end of such a stationary cast can be tacked on to the end of shallower casts obtained while the ship is moving.

The MVP fish can either be user-deployed or deployed automatically by the computer at a user defined time interval. Rainier employs the user-deployed method due to the danger of an automatic deployment taking place during a turn. Casts with the MVP are taken as often as every 15 minutes. This high frequency is due to the ease of collecting casts while losing no survey time stopping for a SEACAT cast. Frequent sound speed casts also better define the sound speed variation over the larger horizontal distances covered by the ship since long, straight lines are preferable to minimize turns while the MVP is deployed.

Rainier had a hydraulic hose casualty on August 6, 2020 that made the MVP inoperable for the remainder of the 2020 field season; repairs are scheduled for the winter of 2020/2021.

Data Processing Methods and Procedures

Downloading and processing of sound speed data is performed using Velocipy, a part of the HSTB supplied Pydro program suite. Both raw and processed CTD files are archived and submitted to the hydrographic branch as part of the sheet submission package.

For Seacat CTD:

- After a cast, the SBE Seacat is connected to the download computer with a serial cable.
- After starting Velocipy, “File/ Download from SBE” is selected from the dropdown menu. A window showing available casts is then displayed with checkboxes to select cast(s) for download.
- After download the user is then required to enter cast metadata. Empty slots for Project, Survey, NOAA Unit, Instrument, Username, Process Date, Draft, and Latitude and Longitude are given.
- After entering metadata, the sound velocity graph is viewable by clicking on the SV tab in the Metadata window. The user can change the sound speed/depth units (X and Y buttons), zoom in (Magnifier tool), and take a look/edit cast points (+ button). Additional tabs display the Temperature and Table view.

• Casts are exported into CARIS SVP format files by selecting File/Export Selected Profiles. A File Export Settings window will pop up, allowing the user to point to the CARIS/ SVP folder and if necessary append the current cast. After clicking OK, the Log Window should read 'exported sound speed profile successfully'.
• To prepare for the next cast, SEACAT PreCast Setup is selected to clear all memory and initialize the profiler for the next cast.

For MVP:

• For the MVP, casts are typically processed as a group at the end of the day or survey watch.
• After starting Velocipy, "File/ Load Profiles" is selected from the dropdown menu. Navigate to the s12 file produced by the MVP and select file/s to process.
• After the files load, the user is then required to enter cast metadata. Empty slots for Project, Survey, NOAA Unit, Instrument, Username, Process Date, and Draft are given. Unlike the Seacat CTD, Latitude and Longitude are already populated.
• After entering metadata, the sound velocity graph is viewable by clicking on the SV tab in the Metadata window. The user can change the sound speed/depth units (X and Y buttons), zoom in (Magnifier tool), and take a look/edit cast points (+ button). Additional tabs display the Temperature, Salinity and Table view.
• Casts are exported into CARIS SVP format files by selecting "File/Export Selected Profiles". A File Export Settings window will pop up, allowing the user to point to the CARIS/ SVP folder and if necessary append the current cast. After clicking OK, the Log Window should read 'exported sound speed profile successfully'.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed values are measured by a SVP 70 on Rainier and on all Jensen survey launches. These sound speed values are applied in real-time to all MBES systems to provide refraction corrections to flat-faced transducers and are used in active beam steering. Launch 2701 has no surface sound speed sensor.

Data Processing Methods and Procedures

Surface sound speed data are not independently processed.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Rainier's primary bathymetric data review and quality control tool are the CARIS CUBE (Combined Uncertainty and Bathymetry Estimator) BASE surfaces as implemented in CARIS HIPS. The CUBE algorithm generates a surface consisting of multiple hypotheses that represent the possible depths at any given position. The BASE surface is a grid of estimation nodes where depth values are computed based on the horizontal and vertical uncertainty of each contributing sounding as follows:

• Soundings with a low vertical uncertainty are given more influence than soundings with high vertical uncertainty.

• Soundings with a low horizontal uncertainty are given more influence than soundings with a high horizontal uncertainty.

• Soundings close to the node are given a greater weight than soundings further away from the node.

As soundings are propagated to a node, a hypothesis representing a possible depth value is developed for the node. If a sounding's value is not significantly different from the previous sounding then the same or modified hypothesis is used. If the value does change significantly, a new hypothesis is created. A node can contain more than one hypothesis. As node-to-node hypotheses are combined into multiple surfaces through methodical processing, a final surface that is the best representation of the bathymetry is created.

Any individual sounding’s uncertainty, or Total Propagated Uncertainty (TPU), is derived from the assumed uncertainty in the echosounder measurement itself, as well as the contributing correctors from sound speed, water levels, position, and attitude. TPU values for tide and sound velocity must be entered for each vessel during TPU computation, unless using TCARI, where uncertainty is added directly to survey lines by Pydro.

• Tide values measured uncertainty value error ranges from 0.01m to 0.05 m dependent upon the accuracy of the tide gauges used and the duration of their deployment. Rainier is using a value of 0.0 since the Tide Component Error Estimation section of the Hydrographic Survey Project Instructions now includes the estimated gauge measurement error in addition to the tidal datum computation error and tidal zoning error.

• Tide values zoning (if applicable) is unique for each project area and typically provided in Appendix II of the Hydrographic Survey Project Instructions, Water Level Instructions. In section 1.3.1.1 of the Water Level Instructions, Tide Component Error Estimation, the tidal error contribution to the total survey error budget is provided at the 95% confidence level, and includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. Since this tidal error value is given for two sigma, the value must be divided by 1.96 before it can be entered into CARIS (which expects a one sigma value). If TCARI grids are assigned to the project area, this value is set at 0.0 since TCARI automatically calculates the error associated with water level interpolation and incorporates it into the residual/harmonic solutions.

• Measured sound speed value error ranges from 0.5 to 4 m/s, dependent on temporal/spatial variability. Although the FPM recommends a value of 4 m/s when one cast is taken every 4-hours, Rainier experience in the field indicates that a value of 3.0 m/s better models this error. If the ship measures sound speed with the MVP, a value of 1.0 m/s is used due to the higher sampling frequency. In cases where XBT casts are used on a sheet, the recommended value of 4.0 m/s is used.

• Surface sound speed value is dependent on the manufacturer specifications of the unit utilized to measure surface SV values for refraction corrections to flat-faced transducers. The Reson SVP 70 fixed-mount sound velocity probe is affixed to launches 2801 2802, 2803 and 2804 to provide correctors for the flat faced EM2040. A redundant pair of Reson SVP 70s is mounted on Rainier to provide correctors for the EM710.

The Reson SVP 70 velocity probe has a published accuracy of 0.05 m/s. A value of 0.0 m/s is used for launch 2701, which has no surface sound speed sensor.

• When a sheet has the requirement to acquire survey data vertically referenced to the ellipsoid, and converted to MLLW using VDatum, the separation uncertainty value replaces the tide zoning value in the calculation of TPU. The separation uncertainty value is included in the Vertical Control Requirements section of the Project Instructions. If a PMVD – now known as ERTDM (ellipsoidally-referenced tidal datum model) is used, the one-sigma modeled uncertainty for the ERTDM is either included with the ERTDM in the project files, or included in the ERTDM email from HSTB.

All other error estimates are read from the Hydrographic Vessel File (HVF) and Device Model file. The HVF contains all offsets and system biases for the survey vessel and its systems, as well as error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements. In addition, the HVF specifies which type of sonar system the vessel is using, referencing the appropriate entry from the Device Model file.

In addition to the usual a priori estimates of uncertainty, some real-time and post-processed uncertainty sources were also incorporated into the depth estimates of Rainier surveys. Real-time uncertainties from the Kongsberg EM2040 and Kongsberg EM710 were recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with navigation and GPS Height applied in CARIS HIPS via an SBET RMS file generated in POSPac.

TPU Calculation Methods

There are two places in CARIS where the user directly defines uncertainty values for use in CARIS to calculate TPU values, in the HVF and the direct input of SV and tide values during the TPU computation.

Source of TPU Values

TPU values for all motion, navigation position and timing values are taken directly from Appendix IV (Uncertainty values for use in CARIS with vessels equipped WITH an attitude sensor) of the Field Procedures Manual. All timing values were set to 0.005 seconds as outlined for setups with Ethernet connections and precise timing.

All offset values were chosen to be 0.010 meters based on the accuracy provided by professional surveys.

All MRU alignment values are derived from the patch test. The gyro value is taken directly from the standard deviation of the yaw values. The pitch/roll value is combined as one in the HVF and is computed as the square root of pitch standard deviation squared plus roll standard deviation squared.

For survey launches the vessel speed uncertainty is defined as 0.03 m/s plus an average value (assumed to be 0.05 m/s) for currents for a total of 0.08 m/s. Vessel loading was determined by measuring the waterline of a single launch under a variety of fuel loading conditions (full, empty, and somewhere in between) and the standard deviation calculated. Vessel draft was determined by measuring the waterline 3 times from both the starboard and port side of each launch. The standard deviation was calculated individually for each side and the larger of these two values was selected for the HVF. Vessel delta draft was determined by measuring the standard deviation of the depth for each speed (RPM) in the dynamic draft determination. The largest of these values was selected for the HVF.

For Rainier, the vessel speed uncertainty is defined as 0.03 m/s plus an average value (assumed to be 0.05 m/s) for currents for a total of 0.08 m/s. A vessel loading of 0.025m was used for the ship based on the recommended value range in the HSSD. The vessel draft of 0.021m was also determined based on the recommended value range in the HSSD. Vessel delta draft was determined by measuring the standard deviation of the depth for each speed (RPM) in the dynamic draft determination. The largest of these values was selected for the HVF.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		2701_CV200	S221_Simrad-EM710_ICE	2801_EM2040	2802_EM2040	2803_EM2040	2804_EM2040
Motion Sensor	*Gyro*	0.05 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.05 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Pitch	0.05 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		2.00 meters	1.00 meters	1.00 meters	1.00 meters	1.00 meters	1.00 meters

C.6.2.2 Real-Time Uncertainty

Vessel	*Description*
All MBES systems.	As previously discussed in this section, some real-time uncertainty values are incorporated into the depth estimates of Rainier surveys by way of post-processing. Real-time uncertainties from the Kongsberg EM2040 and Kongsberg EM710 are recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel GPS height and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.
2701_CV200	As previously discussed in this section, some real-time uncertainty values are incorporated into the depth estimates of Rainier surveys by way of post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. In addition, the post-processed uncertainties associated with vessel GPS height and navigation are applied in CARIS HIPS with the RMS file generated in POSPac.

C.7 Shoreline and Feature Data

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

Prior to shoreline verification the sheet manager prepares boat sheets, page sized chartlets with features color coded by assignment flag and/or source and printed on waterproof paper. Multiple boatsheets covering different sections of a sheet may be created. The scale each boatsheet is determined by the legibility of the features; enough room must be left to annotate each assigned feature by hand. Annotation of features is done in near real time and includes information such as observed time and height, photo number, and remarks. Sheet limits, final feature files, and charts must also be pre-loaded on the acquisition computer.

Shoreline verification is conducted during daylight periods near predicted MLLW tides of +0.5m or less. A line is run along the shore approximating the position of the Navigational Area Limit Line (NALL). Thick near-shore kelp often dictates the position of the NALL. In the absence of direction to the contrary, the NALL was the furthest offshore of the following:

• The 3.5m depth contour at MLLW.
• A line seaward of the MHW line by the ground distance equivalent to 0.8mm at the scale of the largest scale raster chart of the area.

This definition of the NALL is subject to modification by the Project Instructions, Chief of Party (Commanding Officer), or the Hydrographer-In-Charge of the survey launch based on field observations. Some likely additional reasons for modifying the position of the NALL included:

• Sea conditions such as kelp or breakers in which it is unsafe to approach the shore to the specified distance or depth.
• Regular use of waters inshore of this limit by vessels navigating with NOAA nautical chart products. (This does not include skiffs or other very small craft navigating with local knowledge.)

As the approximate NALL line is run along the shore, the hydrographer both annotates the shoreline reference document and scans the area for features to be addressed. All features with CARIS Notebook custom attribute “asgnmt” populated with 'Assigned' and offshore of the NALL are fully investigated. 'Assigned' features inshore of the NALL are verified or DP’d for height if exposed but survey vessels do not navigate inshore of the NALL to either disprove or investigate potential submerged 'Assigned' features. Features are addressed in the following manner:

Offshore of the NALL:
• A feature found within 2mm at survey scale of the composite source position has its height/depth determined.
• A feature outside 2mm at survey scale of the composite source position has its field position revised in addition to a heights/depth determination.
• Features with any linear dimension greater than 1mm at survey scale are treated as an area and delineated.
• New features not in the Composite Source file.
• Maritime boundary points and other features specifically identified for investigation.

Inshore of the NALL:
• Assigned maritime boundary points only if they are safe to approach.
• Navigationally significant features that:
- Are sufficiently prominent to provide a visual aid to navigation (landmarks). Note that rocks awash are almost never landmarks, but distinctive islets or other features visible at MHW can be useful for visual navigation.
- Are within a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area. Common examples of these features include foul areas and large reef/ledge structures.

- Are man-made permanent features connected to the natural shoreline (such as piers and other mooring facilities) larger than the resolution specified for the survey. Seasonal features will be evaluated by the Command.
- Are man-made permanent features disconnected from the shoreline, such as stakes, pilings, and platforms, regardless of size.

Navigationally Significant features were defined as the following:
Small, private mooring facilities (piers and buoys) suitable for pleasure craft are not generally considered navigationally significant. Areas with a high density of mooring buoys for these vessels are delineated, but the features themselves not individually positioned.

Terminology used for field annotation of the shoreline reference document during shoreline verification is as follows:

“Noted”
The existence of a feature and its characteristics are confirmed from a distance, and its position appears to be correct within the scale of the chart or source.
• Appropriate for features inshore of the limit of hydrography and not navigationally significant, significant features that require no further investigation, or features unsafe to approach to verify position within survey scale.
• Noted features are annotated on the shoreline reference document but carried no further forward in the processing pipeline.

“ Verified "
The feature’s position and characteristics are acquired and recorded by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning is generally by DGPS methods.
• Appropriate for navigationally significant features inshore of the limits of hydrography. Also, appropriate for existing features that do not require a height (VALSOU or HEIGHT attribute).

“DP for Height”
The feature’s source position is correct, but height (VALSOU or HEIGHT attribute) is either unknown or incorrect. This position does not supersede that of the source data, so it is only necessary to approach the feature as closely as required to accurately estimate the height.
• Appropriate for source features found within 2mm at survey scale, but with incorrect or missing height or depth data.

“New"
The feature’s position and attributes (including height) are acquired and recorded by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning is generally by DGPS methods.
• Appropriate for items offshore of the NALL that are not present in the Composite Source.
• Items inshore of the NALL that are navigationally significant and are not present in source data.

“Not Seen”
The feature was present in source data but was not visually observed in the field. Full disproval search (see below) was not conducted.

• Appropriate for features above MHW, the absence of which can be proven visually from a distance.
• Source features inshore of the limit of hydrography that are not observed, but whose presence on or absence from the survey will not affect safe navigation.
• Any feature from source that was not seen, but for which full disproval search (see below) is impractical or unsafe.

"Disproved"
The feature is present in source data, but was not located after a full search. "Full Search" means MBES, SBES, SSS, and/or Detached Position coverage of the area that conclusively shows that the item is not located at the position given to the accuracy and scale of the source document.

The primary purpose of detached positions (DPs) is to verify and define shoreline features (ex: rocks, reefs ledges, piles), disprove charted features, position navigational aids and landmarks (ex: buoys, beacons, lights), and mark positions of bottom samples. Point features are captured in the field as height attributed targets in HYPACK.

The survey vessel's track may also be used to delineate area features, such as reefs, ledges, or foul areas. Where it is safe to approach these features to within the specified horizontal accuracy requirement, this method can produce a more accurate and efficient representation of large features than would be provided by multiple DPs on the extents.

A vessel's track may also be used to position point features. Typically while driving a buffer-line around the feature in question, the shoreline vessel will loop back around and drive straight towards the feature and approach as close as is safely possible, often with the nose of the skiff nearly touching the feature. It is then elementary to position the feature based on the pointing "arrow" that the track-line creates.

Rainier entered into the 2020 field season with the understanding that HSD expected all features to be delivered reduced to MLLW by way of the ellipse. This expectation necessitated a change of workflow for features positioned using the skiff's backpack GPS since the antiquated GPS receiver lacks the ability to produce a survey quality ellipsoidal height. Post –processing to MLLW by way of the ellipse using the NOAA created program SHAM (SHoreline Attribution Machine) is possible but requires a nearby launch with a POS MV logging data concurrent with skiff shoreline acquisition. Typically this need is met by RA2 which is typically assigned to collecting lidar heights on the same sheet as the skiff during shoreline windows. In the event that RA2 data is not available, examination of separation model slopes has shown that any launch running on the same sheet can provide adequate vertical positioning.

Issues with the calibration of RA2's Velodyne LiDAR system did not allow for laser heights to collected during the first leg of OPR-O392-RA-20 (September 1st - 15th). Configuration issues with the LiDAR were resolved during the second leg of the project but time constraints and limited shoreline window opportunities did not allow for a patch test confirmation. During this time RA2 collected shoreline in the same manner as a skiff, and using her own POS MV data and SHAM to post-process feature heights to MLLW by way of the ellipse.

Figure 19: Survey skiff RA7 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.

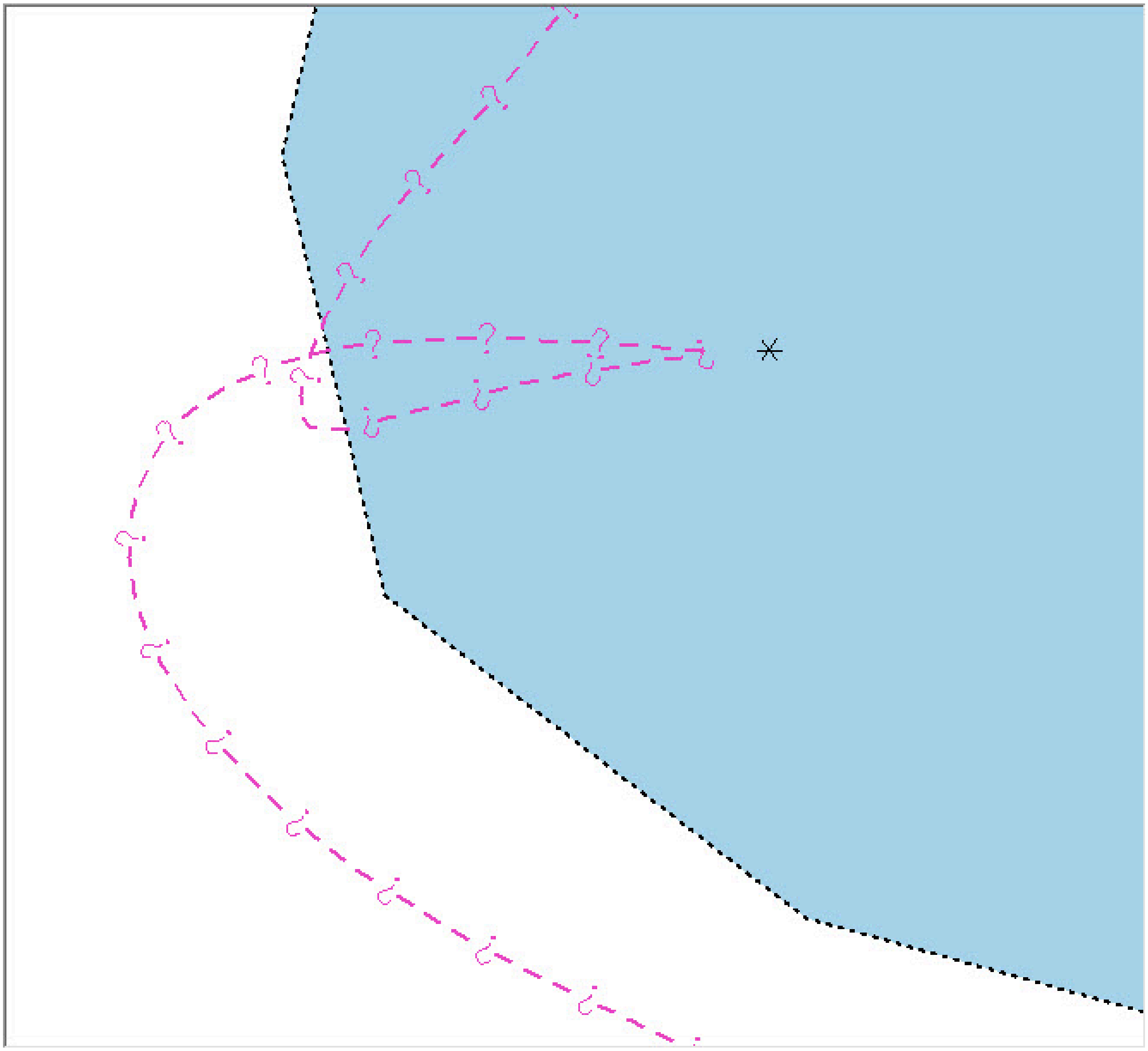

Figure 20: The magenta track-line collected in the field with a skiff and CARIS Notebook used to position a new rock.

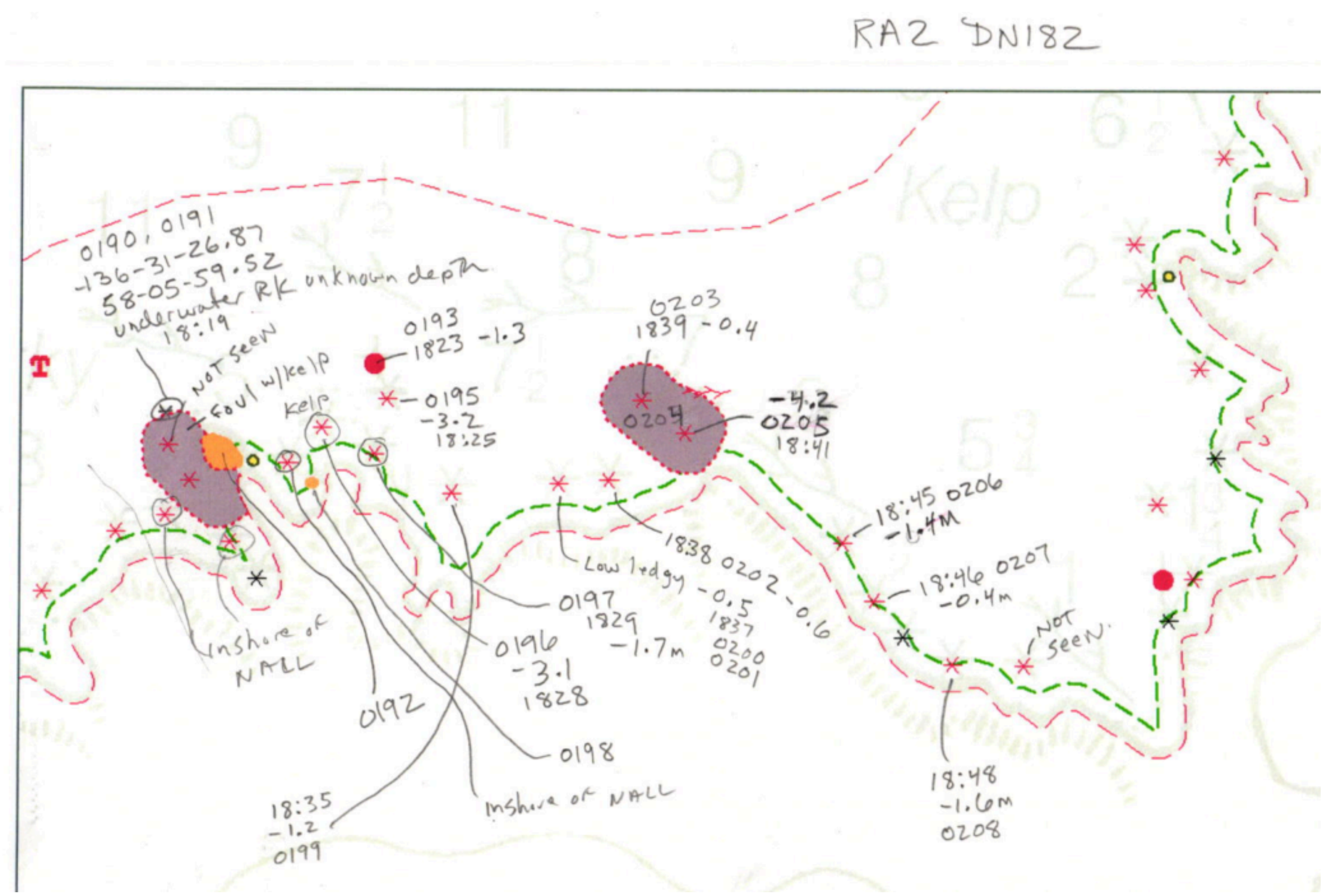

Figure 21: Example of a boatsheet after attribution by hand.

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

Following a day of shoreline verification, the HIC makes digital copies of the notes recorded on the paper boat sheets. In addition, any digital photos taken and the trackline hob file are archived in the appropriate folders of the sheet directory. Field annotations are transferred from the boat sheet into the appropriate S57 attribute fields. Digital photos are also linked to the corresponding feature.

Rainier entered the 2020 field season with two distinct methods of reducing the heights of features to MLLW by way of the ellipse:

- Collect height and position data by way of RA2’s Velodyne LiDAR system and POS MV unit. Final reduction to MLLW is accomplished with SHAM using position data from the POS MV, feature height from the LiDAR, and ellipsoidal height from the POS MV. Heights of features are determined in near real time by the launch crew using a point-cloud of LiDAR data displayed on the acquisition computer. The maximum number of dots in the point cloud available for feature height selection is limited by available computer memory, and can only be accessed in near real time for a limited duration before being written to the hard drive.

- Collect height and position data the traditional manner in a skiff using a GPS backpack and deriving heights by eye or using sounding poles or lead lines. Final reduction to MLLW is accomplished with SHAM using position data from the skiff backpack GPS, feature height collected manually, and ellipsoidal height from the POS MV of a nearby launch.

For features collected with the Velodyne LiDAR system the processing procedure the end of the day is as follows:

• Ensure that the .TGT file is in the correct format, all features need a HYPACK feature code or they will not be recognized as features further down the processing pipeline.

• Import the target file into HYPACK, they will show up as “Targets” under “Project Items”.

• Using the HYPACK ENC Editor, create a new chart with proper geographic limits and attribution. In ENC Editor, select the ENC -> Import -> Targets; they will be displayed on the “Import Targets” tab.

• Convert imported targets to s57 features. As individual targets are converted, they will show up as features on your chart. Save the chart as a .000 (s57) file.

• In HYPACK, export the Targets as a CSV file. This step is needed since the feature height information is not included in the S57 file just created.

• In Pydro start SHAM, (the Shoreline Attribution Machine)
- Select Velodyne, ERS and NAD83.
- Point to the .000 (s57) file and .csv file created in the previous steps.
- Point to SBET file
- Select either VDatum or ERTDM and point to appropriate separation file in CSAR format
- Attribute sheet, vessel and last date of acquisition
- Click on the “Start” button

• SHAM processes the provided information and produces a new, fully attributed .000 (s57) file with feature heights computed.

For features collected in the traditional way, the processing procedure the end of the day is as follows:

• Ensure that the POS MV .000 file of the launch providing vertical control has been processed using POSPac, and a valid SBET been created.

•At bare minimum, the “obstim” and “obsdpt” attributes of all features needing heights reduced to MLLW by way of the ellipse must be correctly attributed using time and height information hand annotated on the boat sheet. The “obstim” attribute is needed to sync the time that the “obsdpt” was recorded with the SBET, and hence an ellipsoidal height value. Optionally, if photos are linked using the "images" attribute, they will be renamed according to HTD 2018 guidance.

• In Pydro start SHAM, (the SHoreline Attribution Machine)

- Select Traditional, ERS and NAD83.
- Point to the .000 (s57) created in the previous steps.
- Point to SBET file
- Point to images folder (optionally) to have all photos renamed according to HTD 2018 guidance
- Select PMVD and point to appropriate separation files (MLLW & MHW) in CSAR format
- Enter a Waterline value of the vessel supplying the SBET file
- Attribute sheet, vessel and last date of acquisition (if known)
- Click on the “Start” button

• SHAM processes the provided information and produces a new, fully attributed .000 (s57) file with feature heights computed.

For surveys where limited shoreline verification was performed, DPs and/or CARIS VBES/MBES CUBE surfaces were used to help define kelp and foul areas. Any new line features were digitized in the HXXXXX_ Final_Features_File.hob file. If an area feature required modification, a copy of the feature was edited to reflect the current survey and characterized as "new" while the original feature was flagged as "delete". When objects were added or modified as “new”, the SORDAT and SORIND fields were updated. All features flagged as "delete" always maintain their original SORDAT and SORIND.

De-confliction of the composite source shoreline was conducted only on items specifically addressed in the field while conducting shoreline verification. As a general rule, nearly all features inshore of the NALL line are not investigated. All conflicting composite source features that are not addressed in the field were left unedited in the final features file HOB.

Composite source features offshore of the NALL which were DPed for height were also de-conflicted if multiple shoreline features were present representing the same item. The source item most closely representing the actual feature was flagged “Primary” and “retain” or “update” if edited for height while the other extraneous features were flagged “Secondary” and “delete” with a comment “removed due to deconfliction". In the event that a DP was taken to reposition an incorrectly charted feature, all of the composite source features in the wrong position were “Secondary” and “delete”.

Primary and secondary flagged features are correlated using the NOAA custom attributes prkyid (Primary Key ID) and dbkyid (Database Key ID). The primary feature has its dbkyid populated with a unique number and any secondary features selected to be linked has its prkyid updated with the same number. The unique number assigned is typically the CARIS Feature Object ID (FOID).

On occasions when the conditions are right, a MBES launch may end up surveying close to the inshore survey limits and end up collecting a significant number of soundings inshore of the NALL. Any additional soundings collected inshore of the NALL were processed as follows:

• “Good” seafloor is not rejected anywhere. Any bad soundings are cleaned out to make the surface represent the seafloor, but there is no cut-off of soundings shoaler than the 4-meter or 0-meter curves. Negative soundings are fine so long as they accurately represent the bottom.

• No launch is to go inside the NALL line trying for the 0-meter curve, or developing items that are found outside the survey limits (i.e. NALL line)

• For cultural features (pilings, piers, buoys and buoy chains, etc.) that are above MLLW (i.e. negative sounding) AND on the CSF HOB layer, all soundings on the cultural item are deleted. This technique will prevent the BASE surface from being pulled up for features already charted above MLLW in the HOB file.

• For cultural features that are below MLLW, the shoalest sounding is designated (which the BASE surface will honor) AND the feature is included on the field verified HOB file.

• For cultural features that are above MLLW and are not on the field verified HOB file, the least depth is flagged as "outstanding," but not included in the BASE surface and all other data on the object is rejected. In this case, the "outstanding" sounding is used as a basis for creating a new feature in the field verified HOB, but it will not affect the BASE surface. This is accomplished by using the option in BASE surface creation to not include outstanding soundings. Alternatively, in the case of area-type cultural features, all depths may be temporarily retained and the resultant DTM used to digitize the feature. Once digitization is complete, all soundings on the cultural item are deleted.

• Rocks and reefs are treated as "seafloor." No data is rejected on rocks, reefs or ledges, even above MLLW. The primary method of getting heights on rocks will remain laser heights using LiDAR, but if a least depth of a rock is obtained with MBES, it will be designated and the height/depth will be used as the VALSOU in the FFF HOB. As previously stated, launches will not go inshore of the NALL line trying to get these data, but it will not be discarded if they are obtained. In cases where the echosounder data does not get the least depth, the soundings obtained will be left in the surface and a DP (or previously acquired comp source data) will be used for the feature.

Following acquisition, digital photos are renamed with an unique ID and moved into the "Multimedia" folder. Any required application of tide and SV corrections are performed in CARIS Notebook. Prior to final survey submission, all images associated with the Final Feature File are renamed using the Pydro program “Rename FFF Images”. This Beta/Experimental program renames all of the FFF images to conform with HTD 2018-5 (Feature Image File Naming Convention).

S-57 Attribution

With the advent of custom CARIS support files supplied by OCS, feature flags previously available only in Pydro are now supported in CARIS HIPS/SIPS, Bathy DataBASE, and Plot Composer. All feature flagging can now be accomplished in CARIS HIPS/SIPS while Pydro is used for generating reports and performing QC.

Features are selected for investigation by HSD OPS based on distance from MHW. Project Instructions and the HSSD require that “All Composite Source File (CSF) features with the NOAA extended attribute ‘asgnmt’ populated with ‘Assigned’ shall be addressed and included in the FFF.”

No Rainier launches will venture inshore of the NALL, even for assigned investigation items, if there is a question of safety or potential equipment damage. If the feature in question is exposed, time and height attributes are assigned while driving past. If the feature is not evident while driving the NALL during shoreline verification, a remark of “inshore of NALL not investigated” is made with a recommendation of "Retain as charted".

Feature attribution is completed for all 'Assigned' and any newly discovered items. Unassigned features are left untouched.

Submerged features, such as wrecks and submerged piles designated in CARIS HIPS are also be brought into Notebook for attribution.

All features marked as “primary” are edited to have their object/attribute instances describe each feature as completely as possible. Object attributes assigned to each feature conform to direction located within both the current HSSD and the CARIS “IHO S-57/ENC Object and Attribute Catalogue”. S-57 attribution is not required for those features flagged as "secondary" nor for unassigned features.

NOAA specific attribution in Notebook includes “descrp” with a drop-down menu which is edited to reflect the hydrographer recommendations as follows:

• descrp - new -- A new feature is identified during survey operations. The hydrographer recommends adding the feature to the chart. Also, in cases in which the geographic position of an existing point feature is modified; the newly proposed feature is characterized as "new", while the original feature is flagged as "delete".

• descrp - update -- The feature was found to be portrayed incorrectly on the chart. Update is also used in the case where the feature was found to be attributed incorrectly or insufficiently and is modified to reflect the additional or corrected attribution. Also, for cases in which the geographic extents/position of an existing line feature are modified; the newly proposed feature is characterized as "update".

• descrp - delete -- The feature is disproved using approved search methods and guidelines. The hydrographer recommends removing it from the chart. Also, for cases in which the geographic position of an existing point object is modified; the newly proposed feature is characterized as "new", while the original feature was flagged as "delete".

• descrp - retain -- The feature is found during survey operations to be positioned correctly and no additional attribution was required. The hydrographer recommends retaining the feature as charted.

• descrp – not addressed -- The feature is not investigated during shoreline acquisition, typically because it is either inshore of the NALL or unsafe to approach. The hydrographer recommends retaining the feature as charted.

Features described as "new" and "update" are updated with the SORIND/SORDAT attribution of the current survey.

Features described as "delete", "retain", and "not addressed" have their SORIND/SORDAT attribution remain unchanged.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

For projects where bottom sample collection is required, HSD Operations provides the field unit with a number of recommended bottom sample sites included as part of the shoreline project reference file (PRF). These proposed sample sites, which are encoded as S-57 SPRINGS, are examined by the command and potentially culled based on the actual depths found during survey operations or added to based on good anchorage positions located by the ship.

Samples are collected by launch using one of the bottom samplers described in the equipment section of this report. Once obtained, samples are analyzed for sediment type and classified with S57 attribution, with the most prevalent sediment type listed first. In the event that no sample is obtained after three attempts, the sample site's NATSUR is characterized as “unknown”. Samples are then discarded after field analysis is complete.

Figure 22: Bottom sample analysis using laminated cards with both color and size to classify a sediment sample

Data Processing Methods and Procedures

Samples are processed as part of the Final Feature File (FFF). Once obtained, samples are analyzed for sediment color, size, and type. These results, along with the geographic position, are either recorded digitally or simply written down on a piece of paper. Once back at the ship, each sample becomes a S57 seabed area (SBDARE) point feature. The sediment color, size, and type populate the attributes COLOUR, NATQUA, and NATSUR. All other required attributes are classified with appropriate S57 attribution. In the event that no sample is obtained after three attempts, the seabed feature is retained with a remark "Three attempts, no sample" and the NATSUR characterized as “unknown”.

C.9 Other Data

Data Acquisition Methods and Procedures

No additional data acquisition methods were utilized.

Data Processing Methods and Procedures

Initial data processing at the end of each survey day is the responsibility of the Night Processing Team, or Launch Crew if no Night Processing Team is assigned. The Night Processing Team is typically composed of two crew members, one with at least a year’s experience, and one junior member in training. Daily processing produces a preliminary product in which all gross data problems have been identified and/or removed, and thus can be used by the Survey Team to plan the next day’s operations. The Night Processors complete a data pass down log to inform the Survey Manager and FOO of any notable features or systematic problems in the day’s data.

In addition, the Night Processing Team may be assigned to processing and QC checks of POSPac data. Final application of the POSPac data is the responsibility of the HorCon project manager and/or assistants. The HorCon Project Manager and the Sheet Manager work together to ensure SBETs were properly applying to the survey after post acquisition tasks are complete.

Relatively new to the night processing pipeline is Charlene, an automated night processing and data transfer tool developed by NOAA’s Office of Coast Survey in early 2017. Night processing includes all of those tasks in between raw data collection and a final daily product that occur each night on our hydrographic vessels. Charlene was adopted as the official processing method for all Rainier hydrographic surveys. Charlene allows the user to:

1. Perform verification of raw data
2. Build transfer drive and deliverable directory structure
3. Transfer and verify raw data
4. Process MBES with the CARIS Batch Processor
5. Generate SBETs with POSPac Batch

6. Use NOAA tools like AutoQC, QCTools and TCARI

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

Any CUBE surface created in CARIS includes a number of child layers (uncertainty, hypothesis count, hypothesis strength and standard deviation to name a few) in addition to the depth layer. Through the process of “directed editing” an experienced hydrographer may be able to review and/or edit problematic data not obviously evident by looking the depth layer alone.

Directed editing involves an overview examination of the depth layer in addition to the available child layers to find problems with the data. The hydrographer then jumps to the trouble spots and makes any necessary edits. This processing method makes the assumption that if the surface “looks good” then the underlying data is also good. If a “good” area is examined in subset mode, noise may be present but the CUBE algorithm is doing its job and preventing the surface from being affected. While good at spotting bursts of noise and other data quality issues, directed editing can have issues with finding single sounding fliers that may show up as only a single pixel if at all.

Problem spots in the child layers may be exaggerated by manipulating the colour file in addition to the min/max range. In addition to finding fliers, child layers can also be useful for seeing areas of noisy data not seen in the depth surface due to CUBE doing its job. In addition child layers may cause objects with high hypothesis counts or standard deviation such as wrecks to be easier to spot.

D.1.2 Designated Sounding Selection

On occasion, the resolution of the CUBE surface may not be sufficient to capture the high point of a feature. The hydrographer may designate soundings that are not incorporated in the gridded surface, although they are not required (HSSD). In general, sounding designation solely to adjust the surface is frowned upon and rarely used. Rather, sounding designation is used only when those soundings are of critical importance, such as in the case of Dangers to Navigation (DTONs).

An exception to this reluctance to designate sounding occurs in the case of point features. Although missed shoal points may occur on irregular shoals or rock pinnacles, man-made features such as piles and wrecks are of particular concern. These features have very slender high points that extend far above the surrounding seafloor as well as the CUBE surface. If a feature has been deemed worthy of inclusion in the final feature file (FFF) and has been ensonified by a MBES system, the shoalest point is flagged “designated” in CARIS. This designated sounding both eases the import of the feature in question into the FFF and ensures that the exact height and position of the feature is honored in the finalized VR surface to be submitted. During the “finalization” process, the CUBE surface is forced to honor all soundings which have been flagged “designated”.

D.1.3 Holiday Identification

QC Tools included as part of PydroXL 19 contains the tool “Detect holidays” which now largely automates the identification of holidays in bathymetry data sets. To begin holiday finder, the user selects a grid and survey type (object detection or full coverage). Any empty grid nodes (“holes”) surrounded by populated nodes are identified. Holidays in VR grids are flagged according to the specifications found in the current NOAA NOS Hydrographic Survey Specifications and Deliverables.

The results of “Detect holidays” are output in a number of different file formats for ease of use regardless of the program used for data analysis. Rainier typically uses the S57 (.000) file that can be opened up in CARIS directly over the surface in question for further analysis.

D.1.4 Uncertainty Assessment

QC Tools included as part of PydroXL 19 contains the tool “Grid QA” which now largely automates the computation of grid statistics to ensure compliance to uncertainty and density requirements. The Depth, Uncertainty, Density (if available), and a computed Total Vertical Uncertainty (TVU) QC layer (optional) are used to compute particular statistics shown as a series of plots. The TVU QC is either given to the program in the grid input, or calculated on-the-fly. It is determined by a ratio of uncertainty to allowable error per NOAA and IHO specification.

Grid QA outputs the following plots:

• Histogram of depth; The percentage of nodes per depth group vs depth (entitled “Depth Distribution”).
• Histogram of density; The percentage of nodes per density group vs soundings per node (entitled “Data Density”).
• Histogram of TVU QC; The percentage of nodes per uncertainty group vs node uncertainty as a fraction of allowable IHO TVU (entitled “Uncertainty Standards”).
• Histogram of % resolution; The percentage of nodes per resolution group vs node resolution as a fraction allowable (entitled “Full Coverage” or "Object Detection").

Optional plots include:

• Plot depth vs density; Depth vs soundings per node (entitled “Node Depth vs. Sounding Density”).
• Plot depth vs TVU QC; Depth vs node uncertainty as a fraction of allowable IHO TVU (entitled “Node Depth vs. TVU QC”).

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

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

Pydro now includes the tool “Compare Grids” which now largely automates the comparison of co-located bathymetry data sets. This tool analyzes the difference between two gridded Depth/Elevation layers in CSAR/BAG format. The CSARs and/or BAGs input may be any combination of variable resolution or raster grids. Output consists of two CSAR grids and three plot files containing summary statistics. One of the CSAR output files contains the simple depth differences in a Diff layer. The other CSAR grid contains the layer fracAllowError, the fraction of the IHO-allowable error. As a quality control (QC) measure, cross-lines with a linear nautical total of at least 4% of mainscheme multibeam lines were run on each survey. Then a CUBE surface was created using strictly the main scheme lines, while a second surface was created using only the crosslines. The differences between these two surfaces are then analyzed using the “Compare Grids” tool. Summary statistics generated using “Compare Grids” are incorporated within the Descriptive Report for each survey.

D.1.5.2 Junctions

The Pydro tool “Compare Grids” described above can just as easily be used for junction comparisons as it is for cross-line analysis.

D.1.5.3 Platform to Platform

No platform to platform comparison is typically conducted as part of the standard sheet processing work flow.

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Side Scan Sonar:

No SSS data were collected for this project.

Backscatter:

Backscatter is processed using Fledermaus FM Geocoder Toolbox (FMGT) and the resulting mosaics examined to ensure they processed correctly. No re-acquisition for backscatter holidays or other issues was conducted.

D.2.2 Contact Selection Methodology

No SSS data were collected for any 2020 projects and therefore no contacts were selected.

E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were followed during the 2020 field season. All operations were conducted in accordance with the Office of Coast Survey Field Procedures Manual (April 2014 edition), NOS Hydrographic Surveys Specifications and Deliverables (May 2020 edition), and all Hydrographic Technical Directives issued through the dates of data acquisition. All departures from these standard practices are described in this Data Acquisition and Processing Report and/or the relevant Descriptive Reports.

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

Approver Name	Approver Title	Date	Signature
Samuel F. Greenaway, CDR/NOAA	Commanding Officer NOAA Ship Rainier	10/24/2020	Digitally signed by GREENAWAY.SAMUEL.F.1275635347 Date: 2020.10.24 19:28:55 -08'00'
James B. Jacobson	Chief Survey Technician NOAA Ship Rainier	10/24/2020	JACOBSON.JAMES.BRYAN.1269664017 I am the author of this document 2020.10.24 15:15:38 -08'00'
Matthew B. Sharr, LT/NOAA	Field Operations Officer NOAA Ship Rainier	10/24/2020	SHARR.MATTHEW.BRANDON.1503637126 2020.10.24 15:24:59 -08'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	2020 Wiring Connections.pdf
Sound Speed Sensor Calibration	2020 SV70s Ship.pdf 2018 SVP 70 Calibration Certificates.pdf SBE 19 C0281 16Dec19.pdf SBE 19 P0281 16Dec19.pdf SBE 19 T0281 16Dec19.pdf SBE 19plus C4039 27Nov19.pdf SBE 19plus C4114 18Nov19.pdf SBE 19plus C4306 27Nov19.pdf SBE 19plus C4343 27Nov19.pdf SBE 19plus P4039 27Nov19.pdf SBE 19plus P4114 18Nov19.pdf SBE 19plus P4306 27Nov19.pdf SBE 19plus P4343 27Nov19.pdf SBE 19plus T4039 27Nov19.pdf SBE 19plus T4114 18Nov19.pdf SBE 19plus T4306 27Nov19.pdf SBE 19plus T4343 27Nov19.pdf SBE 19plus V2 C7530 16Dec19.pdf SBE 19plus V2 C7530 16Dec19-Post Cruise.pdf SBE 19plus V2 P7530 16Dec19.pdf SBE 19plus V2 T7530 16Dec19.pdf
Vessel Offset	RA-2 2701.pdf 2801 & 2802 ReportWITHimages.pdf NOAA_2803.pdf NOAA_2804.pdf CFR 83 Ship Survey Report Rev A Survey.pdf
Position and Attitude Sensor Calibration	2020 POS-MV Calibration Report.pdf
Echosounder Confidence Check	Trip Report_WO#01421S_EM710_Checkout_Rainier_NOAA.pdf 2019_Oct_Em710_RX_TX_Rainier_REPORT.pdf
Echosounder Acceptance Trial Results	2017 Rainier_Launch_EM2040_Acceptance.pdf RA_Ice_TxRx_2014-final.pdf NOAA Ship Rainier EM710 Configuration Update 2016_DRAFT.pdf RA_EM710_Coordiantes and Offsets 2016rev.pdf

Additional Report	***File***
2020 Patch Tests Results	2020_Patch_Test.pdf Kukkamaki 2020 HSRR.pdf 2801_EM2040_151045.xlsx 2802_EM2040_151347.xlsx 2803_EM2040_151619.xlsx 2804_EM2040_152312.xlsx S221_Simrad-EM710_ICE_160016.xlsx