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

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	S-L318-RA-18, OPR-L397-RA-18 & S-M955-RA-18
Time Frame:	September - November 2018

LOCALITY

State(s):	California Oregon
General Locality:	Southern California, California & Yaquina River outlet, Newport, Oregon

2018

CHIEF OF PARTY
Benjamin K. Evans, CDR/NOAA

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NOAA Ship *Rainier*
Chief of Party: Benjamin K. Evans, CDR/NOAA
Year: 2018
Version: 4.1
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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)

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 Partial Static Survey	*Date*	2018-06-25
	Performed By	NOAA Ship Rainier personnel conducted measurements using steel tape measure, laser range finder, carpenter level, and steel straight edge. (No NGS survey is yet available for this vessel)

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*	2017-09-03
	Performed By	The installation of new EM2040 multibeam echo sounders required the determination of new offset values. Because of the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, the offsets were determined by combining the previous survey (National Geodetic Survey, March, 2009) with the drawings of the echo sounder mounting plate and transducer dimensions. The mounting bolt holes for the mounting plate was positioned inside the hull relative to the IMU, and the transducer offsets were then determined relative to the mounting holes from the engineering drawing of the mount.
Most Recent Partial Offset Verification	*Date*	2018-04-25
	Method	As part of the 2018 HSRR, spot checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. The relative heights of the port and starboard GPS antennas to the cabin BM were established using an optical level. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the corrected heights were derived.

Figure 3: Rainier survey launch RA3 (2803)

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	The installation of new EM2040 multibeam echo sounders required the determination of new offset values. Because of the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, the offsets were determined by combining the previous survey (National Geodetic Survey, March, 2008) with the drawings of the echo sounder mounting plate and transducer dimensions. The mounting bolt holes for the mounting plate was positioned inside the hull relative to the IMU, and the transducer offsets were then determined relative to the mounting holes from the engineering drawing of the mount.
Most Recent Partial Offset Verification	*Date*	2017-03-30
	Method	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. As part of the 2017 HSRR, spot checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. The relative heights of the port and starboard GPS antennas to the cabin BM were established using an optical level. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the corrected heights were derived.

Figure 4: Rainier survey launch RA4 (2801)

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	The installation of new EM2040 multibeam echo sounders required the determination of new offset values. Because of the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, the offsets were determined by combining the previous survey (National Geodetic Survey, March, 2008) with the drawings of the echo sounder mounting plate and transducer dimensions. The mounting bolt holes for the mounting plate was positioned inside the hull relative to the IMU, and the transducer offsets were then determined relative to the mounting holes from the engineering drawing of the mount.
Most Recent Partial Offset Verification	*Date*	2018-04-30
	Method	As part of the 2018 HSRR, spot checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. The relative heights of the port and starboard GPS antennas to the cabin BM were established using an optical level. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/ roll matrix, the corrected heights were derived.

Figure 5: Rainier survey launch RA5 (2802)

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	The installation of new EM2040 multibeam echo sounders required the determination of new offset values. Because of the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, the offsets were determined by combining the previous survey (National Geodetic Survey, March, 2009) with the drawings of the echo sounder mounting plate and transducer dimensions. The mounting bolt holes for the mounting plate was positioned inside the hull relative to the IMU, and the transducer offsets were then determined relative to the mounting holes from the engineering drawing of the mount.
Most Recent Partial Offset Verification	*Date*	2017-03-21
	Method	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. As part of the 2017 HSRR, spot checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. The relative heights of the port and starboard GPS antennas to the cabin BM were established using an optical level. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the corrected heights were derived.

Figure 6: Rainier survey launch RA6 (2804)

A.1.7 RA7

Vessel Name	RA7	
Hull Number	1907	
Description	Aluminum hull SeaArk survey skiff	
Dimensions	*LOA*	5.7 meters
	Beam	2.8 meters
	Max Draft	0.35 meters

Figure 7: Rainier survey skiff RA7 (1907)

A.1.8 RA8

Vessel Name	RA8	
Hull Number	1905	
Description	Aluminum hull SeaArk survey skiff	
Dimensions	*LOA*	5.7 meters
	Beam	2.8 meters
	Max Draft	0.35 meters

Figure 8: Rainier survey skiff RA8 (1905)

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg Model EM710

S221 (Rainier) is equipped with a hull-mounted Kongsberg EM710, which operates at sonar frequencies in the 70 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 2000 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 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.

Manufacturer	Kongsberg				
Model	Model EM710				
Inventory	*S221*	*Component*	Processor	Receiver	Transducer
		Model Number	N/A	N/A	N/A
		Serial Number	0356	218	unknown
		Frequency	N/A	N/A	70-100 khz
		Calibration	2018-06-08	2018-06-08	2018-06-08
		Accuracy Check	2018-04-07	2018-04-07	2018-04-07

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	*2801*	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM2040-07	EM2040-07	EM2040-07
		Serial Number	40130	257	367
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2018-04-06	2018-04-06	2018-04-06
		Accuracy Check	2018-04-06	2018-04-06	2018-04-06
	2802	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM2040-07	EM2040-07	EM2040-07
		Serial Number	40129	256	373
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2018-04-23	2018-04-23	2018-04-23
		Accuracy Check	2018-04-06	2018-04-06	2018-04-06
	2803	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM2040-07	EM2040-07	EM2040-07
		Serial Number	40125	262	363
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2018-04-18	2018-04-18	2018-04-18
		Accuracy Check	2018-04-06	2018-04-06	2018-04-06
	2804	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM2040-07	EM2040-07	EM2040-07
		Serial Number	40126	244	366
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2018-04-06	2018-04-06	2018-04-06
		Accuracy Check	2018-04-06	2018-04-06	2018-04-06

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.

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>50/200kHz</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. When using differential correctors, the POS MV generates positional data to an accuracy of 0.5-2 meters.

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.

Intermittent problems with the heading accuracy climbing above the ideal cutoff of 0.05° are observed. Heading accuracy is monitored by the hydrographer in real time, and survey operations are temporarily suspended in the event that the error exceeds 0.08°.

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.

Full POSPac data are also recorded on Rainier and all of her survey launches. 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°. 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	535
		Calibration	2018-06-08	2018-06-08
	2701	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	8957	343
		Calibration	2018-03-30	2018-03-30
	2801 (RA4)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7264	693
		Calibration	2018-03-26	2018-03-26
	2802 (RA5)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7162	694
		Calibration	2018-04-23	2018-04-23
	2803 (RA3)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7272	334
		Calibration	2018-04-18	2018-04-18
	2804 (RA6)	*Component*	PCS	IMU
		Model Number	POS MV 320 V5	LN200
		Serial Number	7274	355
		Calibration	2018-03-22	2018-03-22

A.5.2 DGPS

A.5.2.1 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	*n/a*	*Component*	GPS receiver	GPS receiver
		Model Number	Pathfinder Pro XRS	Pathfinder Pro XRS
		Serial Number	0224070094	0224070154
		Calibration	2018-03-28	2018-03-28

Figure 12: A Trimble "backpack" GPS system and battery tied down on the roof of RA2 (2701) during shoreline verification.

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	*n/a*	*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.

Manufacturer	Leica		
Model	DISTO lite5		
Inventory	*n/a*	*Component*	Hand-held laser
		Model Number	DISTO lite5
		Serial Number	40300556
		Calibration	N/A

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.

Currently, issues with RA2s system configuration and offsets have prevented an accurate patch test of the VLP-16 LiDAR on that launch.

<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	2016-04-11	2016-04-11	2016-04-15	2018-01-24

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.

Manufacturer	SEA-BIRD ELECTRONICS, INC.
Model	SBE 19 SEACAT
Inventory	*Component*: CTD *Model Number*: SBE 19 *Serial Number*: 192472 -0281 *Calibration*: 2018-03-22

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	19P 26069-4039 (black)	19P 27151-4114 (yellow)	19P 30319-4306 (blue)	19P 31464-4343 (purple)	4676 (spare)	4778 (spare)	19P-7530 (red)
	Calibration	2018-02-07	2018-02-07	2017-12-30	2017-12-04	2018-01-31	2018-02-10	2018-02-07

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 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, however readings from this sensor are compared to MVP, CTD and/or XBT casts to ensure 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. These SVP 70 are new for the 2018 field season and replace SVP 71s that exhibited corrosion issues in their anodized aluminum bodies.

Manufacturer	Reson Inc.			
Model	SVP 70			
Inventory	*S221 Rainier*	*Component*	Surface sound speed sensor	Surface sound speed sensor
		Model Number	SVP 70	SVP 70
		Serial Number	301302	4408373
		Calibration	N/A	N/A
	2801	*Component*	Surface sound speed sensor	
		Model Number	SVP 70	
		Serial Number	4517079	
		Calibration	2018-02-28	
	2802	*Component*	Surface sound speed sensor	
		Model Number	SVP 70	
		Serial Number	4517077	
		Calibration	2018-03-02	
	2803	*Component*	Surface sound speed sensor	
		Model Number	SVP 70	
		Serial Number	3417109	
		Calibration	2018-03-05	
	2804	*Component*	Surface sound speed sensor	
		Model Number	SVP 70	
		Serial Number	2817018	
		Calibration	2018-03-01	

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

A.6.5.1 Lockheed Martin Sippican Inc. Sea-Air Systems Division XBT Deep Blue

A standard eXpendable Bathy Thermograph (XBT) system consists of a small torpedo-shaped expendable probe, a data processing/recording system, and a launcher. An electrical connection between the probe and the processor/recorder is made when the canister containing the probe is placed within the launcher and the launcher breech door is closed. Communications between the probe and the surface is maintained through a pair of fine copper wires which pay out from both a spool retained in the launcher and one dropped with the instrument. The XBT Deep Blue includes enough wire to cast a maximum depth of 760m (2500 ft).

The XBT Deep Blue is designed to be used while the ship maintains course and speed. The maximum rated ship speed for deployment is 20 knots.

The XBT contains a precision thermistor located in the nose of the probe. Changes in water temperature are recorded by changes in the resistance of the thermistor as the XBT falls through the water. The XBT is capable of temperature accuracies of ±0.1 ºC.

The nose of each expendable probe is precisely weighted and the unit is spin-stabilized to assure a predictable rate of descent. From this rate of descent, probe depth is determined to an accuracy of ±2% and a vertical resolution of 65cm. When the probe reaches its maximum depth (a function of ship speed and the quantity of wire contained within the shipboard spool) the profile is completed and the system is ready for another launch.

XBTs are deployed using the LMA3 hand launcher interfaced with a MK21 Oceanographic Data Acquisition System by a 100’ cable. Data collection is controlled by the MK21 and the buffered I/O stores all the data until it can be read in by the operating system. Every data point is time stamped by an independent clock on the MK21 to ensure no data is lost or skipped. The MK21 is controlled by either a laptop or desktop PC computer via USB.

The operator uses the computer to select the type of probe to be launched along with other parameters to be stored such as date, time and latitude/longitude (by manual input or NMEA string). The computer performs system diagnostics and prelaunch tests and then indicates the probe is ready for launch. The computer then receives probe data during the descent and displays and stores the information. The XBT data is easily translated to an ASCII text format (.edf file) that Velocipy can process into CARIS SVP format files. Since the XBT data itself contains no salinity data, Velocipy creates CARIS SVP files using the depth-temperature data from the XBT augmented with salinity data from the World Ocean Atlas.

<table>
<tr><td>Manufacturer</td><td colspan="4">Lockheed Martin Sippican Inc.</td></tr>
<tr><td>Model</td><td colspan="4">Sea-Air Systems Division XBT Deep Blue</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S221 Rainier</td><td>Component</td><td>XBT Launcher</td><td>Oceanographic Data Acquisition System topside unit</td></tr>
<tr><td>Model Number</td><td>LMA3</td><td>MK21</td></tr>
<tr><td>Serial Number</td><td>162402</td><td>10250</td></tr>
<tr><td>Calibration</td><td>N/A</td><td>N/A</td></tr>
</table>

Figure 16: Deploying a XBT from the port-side bridge wing of Rainier.

A.6.5.2 Markey COM-7X compact CTD winch

Rainier's oceanographic winch system consists of a LCI 9i cable counter and a Markey COM-7X compact CTD winch and 9mm armored cable. Although this system was install on Rainier with the intention of handling towed side scan sonar fish, it is also capable of deploying a CTD while the vessel is at rest.

Manufacturer	Markey		
Model	COM-7X compact CTD winch		
Inventory	*S221 Rainier*	*Component*	CTD winch
		Model Number	COM-7X
		Serial Number	22349
		Calibration	N/A

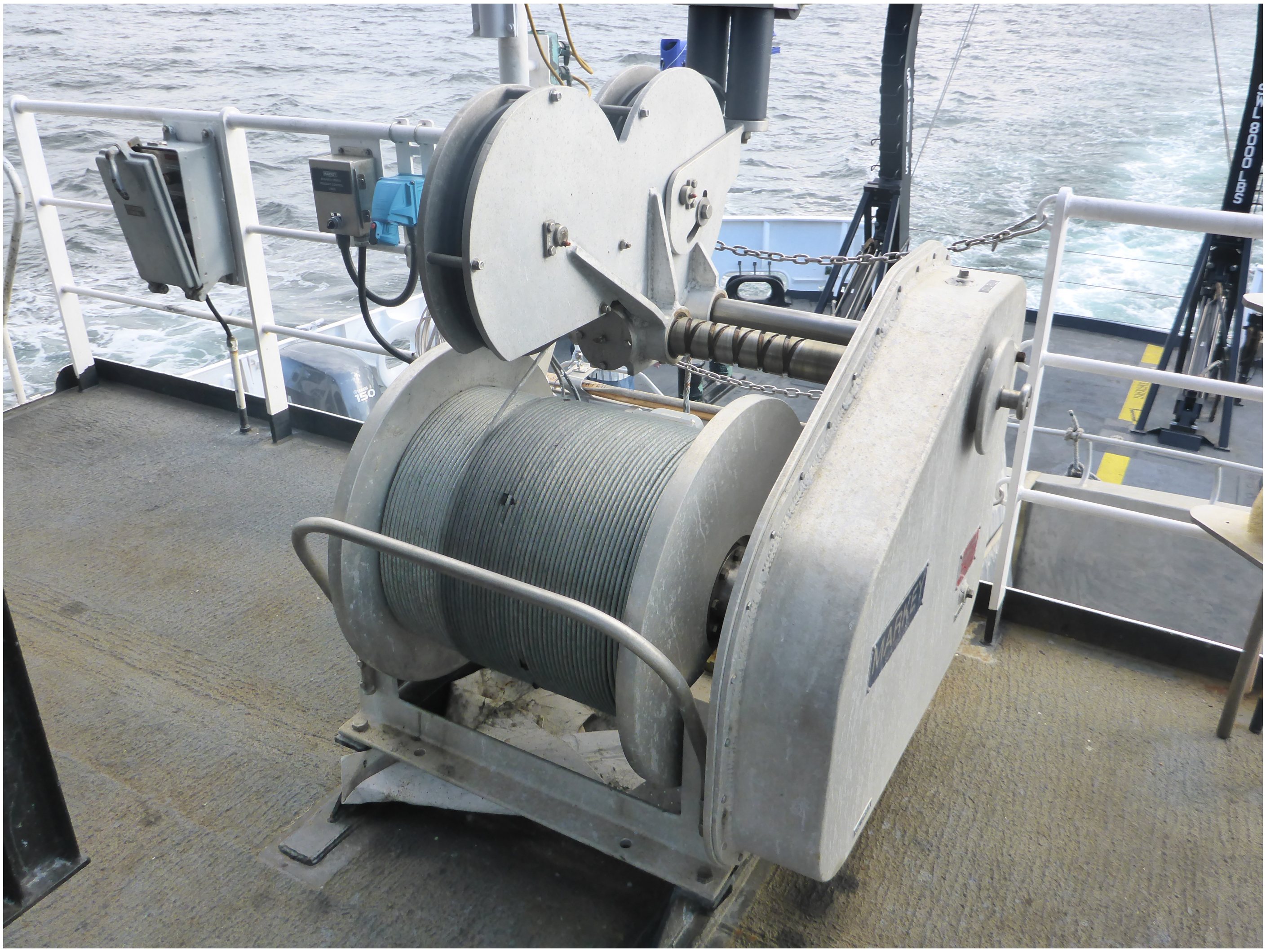

Figure 17: The Markey COM-7X Compact CTD Winch as mounted on the boat deck of Rainier.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
CARIS	HIPS and SIPS (x64)	10.3.3	Processing
CARIS	BASE Editor (x64)	4.4.9	Acquisition
CARIS	Notebook	3.1.1	Acquisition and Processing
Applanix	POSPac MMS	8.2.1	Processing
Fledermaus	FM Geocoder Toolbox (FMGT)	7.8.1	Processing
NOAA (HSTP)	Pydro XL	18.4 (r8470)	Processing
HYPACK, Inc.	Hypack 2017	17.0.34.0	Acquisition
Kongsberg Maritime AS	SIS	4.3.2 build 31	Acquisition
Applanix Corporation	MV-POSView	9.12	Acquisition
ODIM	MVP Controller	2.430	Acquisition
UNH/CCOM	CastTime	18.4 (r8470)	Acquisition
NOAA (HSTP)	Velocipy	18.4 (r8470)	Acquisition and Processing
NOAA (HSTP)	Sound Speed Manager	v.2018.1.39	Acquisition and Processing
NOAA (HSTP)	PydroGIS	18.4 (r8470)	Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

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).

No new vessel dimensional offset surveys of the Rainier launches were conducted in association with the installation of the new EM2040 multibeam echo sounders. Due to the relatively short baselines between the multibeam transducers, the POS MV IMU, and the POS MV antennas, the offsets were determined by combining the previous survey (National Geodetic Survey, March, 2008), the engineering drawings of the echo sounder mount, and a few additional field measurements.

As part of the field measurements, the mounting bolt holes for the 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 entered into the POS MV as well. 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. The TPU fields are largely the same as previously configured, as is the Dynamic Draft table. While changing the reference point (previously on top of IMU) in general changes the observed dynamic draft at that point, in this case, the IMU is essentially directly above the transducer, so the reference point change is insignificant. 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.

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). Ideally the RP should be as close as possible to the center of rotation for the vessel as feasible and this fact was taken into account when positioning the IMU although it is further forward than ideal due to the under-deck layout. 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	2801_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2018-04-06			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		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*	0.00 degrees	
		Roll2	0.00 degrees	

<table>
<tr><td>Vessel</td><td colspan="4">2802_EM2040</td></tr>
<tr><td>Echosounder</td><td colspan="4">Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode</td></tr>
<tr><td>Date</td><td colspan="4">2018-04-23</td></tr>
<tr><td rowspan="16">Offsets</td><td rowspan="7">MRU to Transducer</td><td></td><td>Measurement</td><td>Uncertainty</td></tr>
<tr><td>x</td><td>0.193 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.137 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.537 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>-0.112 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.037 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.521 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.193 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.137 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.537 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>-0.112 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>0.037 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.521 meters</td><td>N/A</td></tr>
<tr><td rowspan="2">Transducer Roll</td><td>Roll</td><td>0.00 degrees</td><td></td></tr>
<tr><td>Roll2</td><td>0.00 degrees</td><td></td></tr>
</table>

Vessel	2803_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2018-04-18			
Offsets			*Measurement*	*Uncertainty*
	MRU 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
	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*	0.00 degrees	
		Roll2	0.00 degrees	

Vessel	2804_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2018-04-06			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		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*	0.00 degrees	
		Roll2	0.00 degrees	

Vessel	S221_Simrad-EM710_ICE			
Echosounder	Kongsburg Simrad EM710 0.5x1			
Date	2018-06-08			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		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*	0.00 degrees	
		Roll2	-0.31 degrees	

Vessel	2701_CV200			
Echosounder	Teledyne Odom Hydrographic Odom Echotrac CV			
Date	2018-06-13			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.252 meters	0.020 meters
		y	-0.610 meters	0.020 meters
		z	0.391 meters	0.020 meters
	Nav to Transducer	*x*	0.252 meters	0.020 meters
		y	-0.610 meters	0.020 meters
		z	0.391 meters	0.020 meters
	Transducer Roll	*Roll*	0.00 degrees	

B.1.2 Layback

No towfish data were collected for this project.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

With one exception, all Rainier survey launches were constructed with integrated benchmarks that were later surveyed by the National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch. Launch 2701 (RA2) was also constructed with integrated benchmarks but lacking a professional vessel survey, these marks were positioned by Rainier personnel. At some point in the future a proper NGS survey for launch 2701 is planned. 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 Jensen survey launches 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 "2018_WaterLine_Loading" report attached to this document.

Launch 2701 initially had her waterline determined following the procedure previously described for Jensen survey launches but on 10/19/2018, the decision was made to remove the waterline value from the HVF and apply it directly in the single-beam sonar system. Due to the lack of a NGS survey for 2701, there was always some concern with the validity of Z-values assigned in the HVF. Poor X-line comparisons with MBES data cast further doubt on the depth values being produced by the single-beam system. In an effort to remove potential sources of error, the decision was made to dial a draft value directly into the single-beam sonar system based on a comparison of live readings vs direct measurement of water depth using a tape measure. The waterline value depicted in this report and used for initial configuration testing is the hand-measured value used prior to 10/19/2018 zeroing out of the value.

For Rainier, static draft is determined by direct measurement to the physical waterline. Draft measurements are taken throughout the field season any time there is major chance in the ship's draft (ex: after fueling). A good time to conduct these measurements is while the ship is inport where motion by both the ship and sea is minimized. The single measurement value entered into the DAPR is taken from the first draft reading than applies to a survey covered by this report. In total, two of the static draft values present in the HVF are applicable to the three projects covered by this DAPR.

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		2801_EM2040	2802_EM2040	2803_EM2040	2804_EM2040	S221_Simrad-EM710_ICE	2701_CV200
Date		2018-04-01	2018-04-01	2018-04-02	2018-04-01	2018-09-11	2018-06-13
Loading		0.016 meters	0.016 meters	0.016 meters	0.016 meters	0.025 meters	0.030 meters
Static Draft	*Measurement*	-0.623 meters	-0.640 meters	-0.632 meters	-0.634 meters	-4.822 meters	0.049 meters
	Uncertainty	0.004 meters	0.004 meters	0.003 meters	0.006 meters	0.021 meters	0.004 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 it was proposed to 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 2018 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 2018 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	2801_EM2040		2802_EM2040		2803_EM2040		2804_EM2040		S221_Simrad-EM710_ICE		2701_CV200	
Date	2015-05-09		2015-04-13		2015-04-13		2015-04-13		2014-01-01		2018-06-13	
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	-0.01	0.50	-0.01	0.50	-0.01	0.50	-0.01	0.50	-0.01	0.50	0.11
	1.00	-0.01	1.00	-0.01	1.00	-0.01	1.00	-0.01	1.00	-0.02	1.00	0.17
	1.50	0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50	-0.01	1.50	0.21
	2.00	0.02	2.00	0.02	2.00	0.02	2.00	0.02	2.00	0.00	2.00	0.22
	2.50	0.03	2.50	0.03	2.50	0.03	2.50	0.03	2.50	0.01	2.50	0.21
	3.00	0.05	3.00	0.05	3.00	0.05	3.00	0.05	3.00	0.03	3.00	0.19
	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.16
	4.00	0.05	4.00	0.05	4.00	0.05	4.00	0.05	4.00	0.08	4.00	0.13
	4.50	0.03	4.50	0.03	4.50	0.03	4.50	0.03	4.50	0.10	4.50	0.09
	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.13	5.00	0.05
	5.50	-0.05	5.50	-0.05	5.50	-0.05	5.50	-0.05	5.50	0.15	5.50	0.01
	6.00	-0.10	6.00	-0.10	6.00	-0.10	6.00	-0.10	6.00	0.17	6.00	-0.03
	6.50	-0.14	6.50	-0.14	6.50	-0.14	6.50	-0.14	6.50	0.19	7.00	-0.10
	7.00	-0.20	7.00	-0.20	7.00	-0.20	7.00	-0.20	7.00	0.21	8.00	-0.14
											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 conducted for all four Jensen launches in Port Madison, WA on April 6th, 2018. Patch test values were derived for each value after the applicable test using CARIS. These values were then entered into SIS before performing the next test. Once all tests were 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.

In their final state, CARIS HFV files 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 back-dated 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.

Due to damage inflicted to their GPS antennas during a tree strike while secured in their davits on April 16th 2018, launches 2802 & 2803 required a new patch test to be conducted after repairs. These tests were conducted in Lake Washington between April 18th and May 4th, 2018.

One instance of non-zero patch values in the HVF did occur after the first hydrographic data was collected. For vessel 2802 DN(131) the final patch test values were entered into the POS/MV for the first day of survey, but the values were not saved. This resulted in patch values being applied to only data collected on DN131 and no patch values applied to any data collected on the following days up to DN(159) when the error was caught. To correct this issue, the HVF was modified to apply patch values from DN113-130 for reference surface processing and experimentation, zero patch values for DN131 when values were entered into the POS/MV but not saved, apply patch values from DN132-158 while the POS/MV patch values were inadvertently set to zero, and finally zero patch values beginning on DN1591 when values were corrected in the POS/MV and saved.

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 installed on board. In spite of the Kongsberg multibeam system working on multiple frequencies (70-100 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. If the patch test results bore this out, the SIS and the POS MV values were considered confirmed and left unchanged.

Due to the peculiarities of system integration, system alignment correctors for the ship are applied in the acquisition software (SIS) rather than in CARIS by way of the HVF. In addition, over the winter the ship's acquisition system stay mounted as installed during the 2014 dry-dock 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 which 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 Swath Editor. Biases were determined using the CARIS HIPS Calibration tool by at least 5 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; timing, pitch, roll, and finally yaw.

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

Vessel	2801_EM2040		
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode		
Date	2018-05-01		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.005 seconds
	Navigation Time Correction	0.000 seconds	0.005 seconds
	Pitch	0.000 degrees	0.131 degrees
	Roll	0.000 degrees	0.131 degrees
	Yaw	0.000 degrees	0.202 degrees
	Pitch Time Correction	0.002 seconds	0.005 seconds
	Roll Time Correction	0.000 seconds	0.005 seconds
	Yaw Time Correction	0.000 seconds	0.005 seconds
	Heave Time Correction	0.000 seconds	0.005 seconds
Date	2018-05-01		
Patch Test Values (Transducer 2)		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.005 seconds
	Navigation Time Correction	0.000 seconds	0.005 seconds
	Pitch	0.000 degrees	0.131 degrees
	Roll	0.000 degrees	0.131 degrees
	Yaw	0.000 degrees	0.202 degrees
	Pitch Time Correction	0.002 seconds	0.005 seconds
	Roll Time Correction	0.000 seconds	0.005 seconds
	Yaw Time Correction	0.000 seconds	0.005 seconds
	Heave Time Correction	0.000 seconds	0.005 seconds

Vessel	2802_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2018-06-08

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.000 degrees	0.050 degrees
Roll	0.000 degrees	0.050 degrees
Yaw	0.000 degrees	0.206 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.000 seconds	0.005 seconds
Yaw Time Correction	0.000 seconds	0.005 seconds
Heave Time Correction	0.000 seconds	0.005 seconds

Date	2018-06-08

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.000 degrees	0.050 degrees
Roll	0.000 degrees	0.050 degrees
Yaw	0.000 degrees	0.206 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.000 seconds	0.005 seconds
Yaw Time Correction	0.000 seconds	0.005 seconds
Heave Time Correction	0.000 seconds	0.005 seconds

<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>2018-05-01</td></tr>
<tr><td>Patch Test Values</td><td>
<table>
<tr><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Pitch</td><td>0.000 degrees</td><td>0.056 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.056 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.154 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>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
</table>
</td></tr>
<tr><td>Date</td><td>2018-05-01</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>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Pitch</td><td>0.000 degrees</td><td>0.056 degrees</td></tr>
<tr><td>Roll</td><td>0.000 degrees</td><td>0.056 degrees</td></tr>
<tr><td>Yaw</td><td>0.000 degrees</td><td>0.154 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>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.005 seconds</td></tr>
</table>
</td></tr>
</table>

Vessel	2804_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2018-05-01

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.000 degrees	0.076 degrees
Roll	0.000 degrees	0.076 degrees
Yaw	0.000 degrees	0.223 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.000 seconds	0.005 seconds
Yaw Time Correction	0.000 seconds	0.005 seconds
Heave Time Correction	0.000 seconds	0.005 seconds

Date	2018-05-01

Patch Test Values (Transducer 2)

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.000 degrees	0.076 degrees
Roll	0.000 degrees	0.076 degrees
Yaw	0.000 degrees	0.223 degrees
Pitch Time Correction	0.002 seconds	0.005 seconds
Roll Time Correction	0.000 seconds	0.005 seconds
Yaw Time Correction	0.000 seconds	0.005 seconds
Heave Time Correction	0.000 seconds	0.005 seconds

Vessel	S221_Simrad-EM710_ICE
Echosounder	Kongsburg Simrad EM710 0.5x1
Date	2018-06-08

Patch Test Values

	Corrector	Uncertainty
Transducer Time Correction	0.000 seconds	0.024 seconds
Navigation Time Correction	0.000 seconds	0.024 seconds
Pitch	0.000 degrees	0.033 degrees
Roll	0.000 degrees	0.033 degrees
Yaw	0.000 degrees	0.039 degrees
Pitch Time Correction	0.000 seconds	0.024 seconds
Roll Time Correction	0.000 seconds	0.024 seconds
Yaw Time Correction	0.000 seconds	0.024 seconds
Heave Time Correction	0.000 seconds	0.024 seconds

Date	2018-06-08

Patch Test Values (Transducer 2)

	Corrector	Uncertainty
Transducer Time Correction	0.000 seconds	0.024 seconds
Navigation Time Correction	0.000 seconds	0.024 seconds
Pitch	0.000 degrees	0.033 degrees
Roll	0.000 degrees	0.033 degrees
Yaw	0.000 degrees	0.039 degrees
Pitch Time Correction	0.000 seconds	0.024 seconds
Roll Time Correction	0.000 seconds	0.024 seconds
Yaw Time Correction	0.000 seconds	0.024 seconds
Heave Time Correction	0.000 seconds	0.024 seconds

Vessel	2701_CV200
Echosounder	Teledyne Odom Hydrographic Odom Echotrac CV
Date	2018-06-13

Patch Test Values

	Corrector	Uncertainty
Transducer Time Correction	0.000 seconds	0.010 seconds
Navigation Time Correction	0.000 seconds	0.010 seconds
Pitch	0.000 degrees	1.000 degrees
Roll	0.000 degrees	1.000 degrees
Yaw	0.000 degrees	1.000 degrees
Pitch Time Correction	0.000 seconds	0.010 seconds
Roll Time Correction	0.000 seconds	0.010 seconds
Yaw Time Correction	0.000 seconds	0.010 seconds
Heave Time Correction	0.000 seconds	0.010 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

For both the Rainier's Kongsberg EM710 and the launch Kongsberg EM2040 systems, shallow water 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.

Rainier initially began the field season installing Hypack 2018 for Hydro System Readiness Review (HSRR) testing but discovered a bug that causes raster charts to be displayed with an offset from their actual position. The ship is reverting to Hypack 2017 for the 2018 season and awaits a fix from Hypack for this issue.

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 ~10% overlap with the previous line. In this way, lines are used to minimize the number of turns and course adjustments required for the relatively un-maneuverable Rainier; 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. Convert the “raw” SIS data to the HDCS data format.
2. Load Delayed Heave.
3. Load predicted tides.

Although observed tides may be available by the time night processing occurs, predicted tides are selected. Experience has shown that attempting to download and apply observed tides using Charlene often results in failure due to intermittent internet conductivity while the ship is at sea. Charlene may not handle this failure well resulting in data being flagged as tide corrected when it isn’t, resulting in a cascade of failures further down the processing pipeline that are difficult to troubleshoot.

4. Load and apply sound velocity files.
5. “Merge” data to apply position, attitude, and dynamic draft correctors to bathymetry and compute the corrected depth and position of each sounding.
6. Compute Total Propagated Uncertainty (TPU).
7. Filters may be applied to the data after checking with the sheet manager if specific data issues exist. If used, data is filtered according to the following criteria:

• Reject soundings with TPU greater than the horizontal and vertical error limits specified in the NOS Hydrographic Surveys Specifications and Deliverables:

Horizontal Error is (5m + 5% of depth)
Vertical Error is ±SQRT(a^2+(b*d)^2) , where “a” and “b” are defined as
- in depth ranges 0-100m, a=0.500 b=0.013
- in depth ranges > 100m, a=1.000 b=0.023

8. Add data to the master “QC” field sheet encompassing the entire survey.

• “QC” Field Sheet naming convention: Hxxxxx_QC (e.g., H12345_QC)
• BASE surfaces are created in accordance with the depth ranges set forth in table below.

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

It has been the experience aboard Rainier that CUBE surfaces of differing resolutions that cover the same dataset may produce widely different results. In an effort to eliminate this problem, CUBE surface resolution values of 1, 2, 4, 8, 16 and 32 meters were chosen. On occasion a 0.5m CUBE surface is utilized in areas of rocky or uneven bottom when the default surface does not well represent all of the shoal points. Since these resolution values are even multiples, all of the surfaces produced for a given field sheet will have the nodes of all surfaces co-located.

The following options are selected when CUBE surfaces were 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 also 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 is not permitted and it is 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 2 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.

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 2701’s primary use 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 Hypack 2017.

Conducting shoreline using 2701 is currently still in an experimental stage. Many issues with system configuration and data transfer issues were still in the process of being resolved. Troubleshooting efforts were brought to an abrupt end while RA2 was tied up alongside Rainier. Due to an inadvertent blockage of an overboard cooling water discharge, seawater sprayed all over the equipment rack damaging the acquisition system. Rainier pieced the system back together while working on Channel Islands project but during integration testing, the single beam echo-sounder topside unit failed and could not be repaired before the field season concluded.

At some point in the future, Rainier may bring both the SBES and LiDAR data into the final submission dataset, but currently 2701 is utilized for shoreline verification in the same manner as a survey skiff. Hypack is used on the acquisition computer for positioning instead of the Trimble backpack and no SBES and LiDAR data is collected.

Data Processing Methods and Procedures

n/a

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 2018 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 2018 surveys.

Rainier initially began the field season creating VR surfaces using HIPS 10.4.2 but soon discovered gaps in coverage that corresponded to resolution tile boundaries. Experimentation aboard the NOAA Ship Fairweather, which was experiencing the same issue, found that HIPS 10.3.3 does not show the same gaps. Correspondence with CARIS (ticket #01801017) postulates that the combination of min/max grid setting values, the depth ranges in a given tile, and the resolutions assigned for a depth-based CARIS VR surface, is causing CARIS to flag the tile as invalid. Later when the PopulateVR process tries to populate the VR surface, the tiles that are all marked as invalid don't get grid nodes, and therefore show up as empty.

The root cause of these unpopulated grid nodes is changes made to the algorithm to address an issue experienced by a number of users prior to the release of HIPS 10.4. While this update fixed one problem, it inadvertently caused this issue. CARIS has no time estimation on how long it will take to resolve this issue and recommends sticking with HIPS 10.3 for as long as we use the depth-based method to create CARIS VR surfaces. Rainier has downgraded back to CARIS HIPS 10.3.3 and intends to stay there until this CARIS bug is fixed.

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 2018 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. 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 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 2018 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 launch's EM2040s and Rainier's EM710.

Data Processing Methods and Procedures

NOAA field units are required to process 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:

- 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.

-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.

-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.

-When creating a mosaic for submission, any crosslines not needed in the mosaic is deselected. Export type is set as grayscale GeoTIFF. Initial guidance at the beginning of the field season recommended no more than 20 MB per mosaic in an attempt to keep the file sizes low to allow for easier distribution through the website and other public forums. Consultation with PHB upped this limit to 35 MB for both S-L318-RA-18 and OPR-L397-RA-18.

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 between 2 and 6 meters horizontally.

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

Data Processing Methods and Procedures

No 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. For further details on individual processing methodology, refer to the HVCR of the appropriate project.

The 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: 3, 7, 20, 102, 111 and 113. The Output Control rate is also set to ‘50Hz’.

Although it is not necessary to break a line that would cross over UTC midnight, during 24-hour operations Rainier makes the effort to break logging as near that time as possible to ease processing bookkeeping. By following this method, a block of ~24 hours of data is processed using Charlene and saved in a Caris DN folder that corresponds to the actual DN of the data. If UTC midnight occurs mid-line, logging will be continued until the end of the line is reached where the record may be broken during the turn. An exception to this procedure occurs at the end of the GPS week (UTC midnight on Saturdays) where it is important not to log through UTC midnight.

For typical launch operations it is not necessary to break a line that would cross over UTC midnight. By following this method, a single POS file is generated during a "launch day". This POS file when processed along with the rest of the launch data creates a single Caris DN folder that may contain a few lines of data collected after UTC midnight. An exception to this procedure occurs at the end of the GPS week (UTC midnight on Saturdays) where it is important not to log through UTC midnight.

Data Processing Methods and Procedures

Rainier utilizes Post Processed Kinematic (PPK) 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 both projects S-L318-RA-18 and OPR-L397-RA-18, 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.

Smart Base:

Smart Base is the preferred method when a minimum of four (six recommended) CORS stations are available for selection near the project area. In situations with a maximum baseline of 70 km, an optimal horizontal accuracy of 3-10 cm should be achieved.

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, exported into WGS84. 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 horizontal accuracy of 10-50 cm should be achieved.

PP-RTX Processing Methodology:

1) Open POSPac MMS 8.2.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 ephemerides 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.

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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 from 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 the Sea-Bird SEACAT conductivity, temperature, and depth profiler (CTD) to acquire sound speed data. Rainier may also use the Rolls-Royce Moving Vessel Profiler (MVP200) or Sippican/Lockheed XBT probes 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), would warrant additional sound velocity profiles. The launch crew also monitors the real-time display of the Reson SVP 71 for changes of 2 m/s or greater in the surface sound velocity indicative of the need for a new cast.

Velocipy 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 project area expected to be surveyed 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.

The Sippican/Lockheed XBT:

For project areas that include depths greater that the maximum range of the MVP (~235m underway, ~600m stationary), Rainier was provided with the XBT probes and launcher that include enough wire to cast a maximum depth of 760m. This depth exceeds the maximum depth of casts possible from the ship with her current winch setup. XBTs have the additional advantage of being deployable while the ship is underway.

Casts from this system are created and downloaded in Sippican/Lockheed software and then processed in Velocipy and Sound Speed Manager.

Data Processing Methods and Procedures

Downloading and processing of sound speed data is performed using Velocipy, a part of the HSTP 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'.

For XBT:

• Open Sound Speed Manager and use the input data button to open that XBT cast.

• Next if your XBT cast hit the seafloor you will need to remove the data from after that event. Use the remove data button and right click and drag a box over the temperature data after the XBT hit the seafloor.
• To add a salinity to the XBT cast use the retrieve salinity button. This will grab a salinity profile for the XBT location from the world ocean atlas.
• Extend the cast using the extend profile button.
• Optionally set the XBT cast as a reference cast using the "ref" button. Later when the MVP cast are imported to sound speed manager this will be used as the reference to extend the cast.
• Save the XBT cast using the export data button.

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 1 cast is taken every 4-hours, Rainier experience in the field suggests that a value of 3.0 m/s better models this error. 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.

• 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.

ERZT SEP Uncertainty Calculation (if applicable)

When a project has a requirement to acquire survey data vertically-referenced to the ellipsoid, Rainier typically employs an ERZT separation model. Although this method creates a custom separation model for each survey, there are no uncertainty values associated with it.

Rainier, with consultation from HSTP came up with the following equation to model the uncertainty of a field derived ERZT separation surface:

SEP Uncertainty = Mean of Standard Deviation/sqrt(Total Linear Nautical Miles/Total 1km Nodes)

The Mean of Standard Deviation is found by:
• Right click on the parent layer of your separation model and choose “Compute Statistics…”
• Choose the Std_Dev layer from the attribute layer drop-down
• Change the bin size to 0.05
• Click OK to compute statistics
• The Mean of Standard Deviation is labeled Mean under Statistics in the “Compute Statistics” output window.

The Total Linear Nautical Miles is found by:
• Select all of your lines.
• In the “Selection” window, highlight all of the lines.
• Right click after highlighting and choose the copy option.
• Open a blank Excel spreadsheet and paste all of the line data
• By clicking on the column label for the length data you will select the entire column. When an entire column is selected, Excel provides a sum of all of the data in that column. It is located in the bottom right corner of the spreadsheet.
• Convert meters to linear nautical miles by dividing by 1852 meters per nm.

The Total 1km Nodes is found by:
• Select all of the nodes in your 1000 m separation model.
• Get the total number of nodes from the bottom of the screen.

During the Compute TPU step in CARIS, the SEP Uncertainty number is used in place of Tide value Zoning during computation of the TPU.

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 vessel roll, pitch, gyro and navigation are 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

A Priori Uncertainty

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

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 roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

Source shoreline data is typically supplied by N/CS31 in a single Composite Source file (CSF) in both S-57 .000 and .hob formats. The CSF is delivered with the Project Instructions and is to be used as the only shoreline data for use in the field. The composite source file is compiled from all available source shoreline files (i.e. ENC, Geographic Cells, lidar, RNC, and Prior Surveys) into a single file in an S-57 .000 format. Additionally, a Project Reference file (PRF) is supplied containing sheet limits, maritime boundary points, and recommended bottom sample sites.

In preparation for shoreline verification, the Survey Manager copies the project wide composite source file and crops it to include only items contained on their assigned sheet. This cropped file is then saved as a HOB file named HXXXXX_Composite_Source.hob. At this point, no further edits are ever made to this HOB file and it is retained as the "starting point" to any subsequent changes discovered during shoreline verification. A copy of the original source HOB file is created and called HXXXXX_Final_Features_File.hob. It is to this final features HOB file that any edits are performed. The HXXXXX_Composite_Source.hob is also saved in an S-57 .000 format which can be directly opened in Hypack for field reference and verification where necessary.

The Survey Manager creates a composite shoreline reference document (commonly referred to as boat sheets), the paper representation of the shoreline that will be used to write down observations in the field. Boat sheets are typically produced on 8 ½" x 11" waterproof paper for easier use in an open skiff. The CSF file may be color coded to highlight any assigned features by using the asgnmt=Assigned field. The resultant color coded shoreline is then sent directly to the printer from Notebook.

In the field, CARIS Notebook is used to acquire DPs and/or modify S-57 attribution of existing features. Edits and DPs were collected on the most current version of the HXXXXX_ Final_Features_File.hob file. An archival copy of the final features file is saved for each day of feature verification. Daily copies are produced in order to aid feature tracking and the eventual compilation of all features in the submission HXXXXX_Final_Features_File.hob. To increase efficiency during the limited shoreline window, the HIC may forgo S-57 attribution with Notebook while in the field and instead take copious notes on the boat sheets for later attribution back on the ship.

While the skiff is actually running along the shoreline and positioning features during shoreline verification, the track line is logged as a generic cartographic line and saved by Notebook as a hob file. This trackline hob file can then be used later to position rocks, foul areas, or kelp and also be used to plan the inner bounds of MBES coverage.

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 (in rare instances) Hydrographer-In-Charge of the survey launch. 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 as defined below.

Navigationally Significant features were defined as the following:

• All features within the limits of safe navigation (i.e., offshore of the NALL).
• Features inshore of the NALL which:
• 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.
• Significantly (a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area) deflect this limit. 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.

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 either 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 either 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 which 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 which are not observed, but whose presence on or absence from the survey will not affect safe navigation.
• Any feature from source which 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 which 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 attributed S-57 objects in CARIS Notebook. Any line objects, such as small piers or foul areas were digitized directly into

CARIS Notebook while in the field. Concurrent with the acquisition of these features, digital photographs are taken of objects which are exposed above the waterline.

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.

Figure 18: Survey skiff RA7 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.

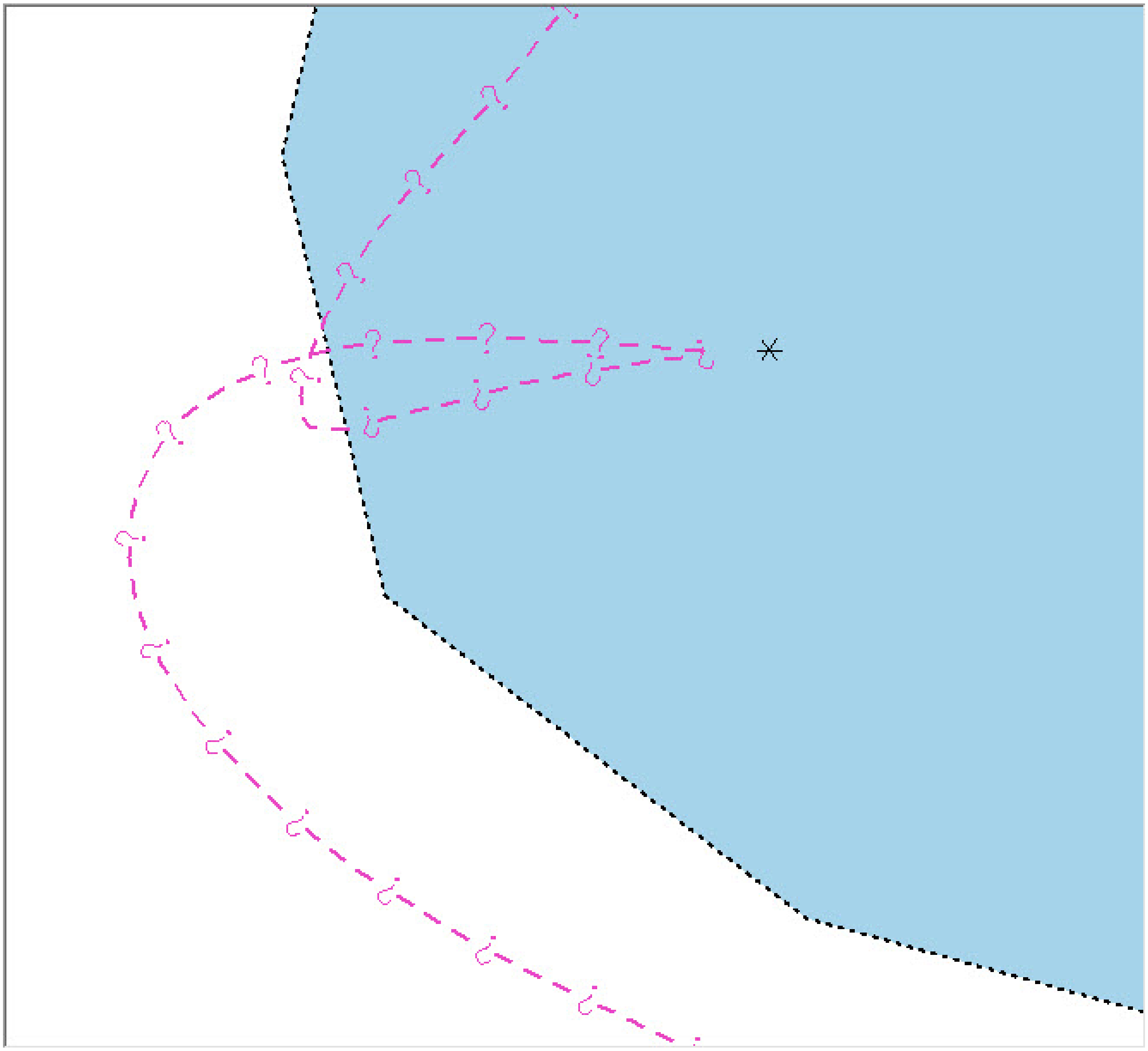

Figure 19: The magenta track-line collected in the field with a skiff and CARIS Notebook used to position a new rock.

Data Processing Methods and Procedures

Following a day of shoreline verification, the HIC copies the HXXXXX_Final_Features_File.hob used in the skiff in addition to any digital photos taken and the trackline hob file. These file are then placed in the appropriate locations in the working projects directory.

Features collected with the Velodyne LiDAR system are attributed in near real-time and saved in a Hypack target file. At the end of the day all the collected S57 targets are imported into the laser CSF (.000) file using the Hypack ENC editor. At this point any rocks that were classified as obstruction features may be corrected with “change selected feature to new feature type.” Finally the S57 features are exported as a .csv file with target attributes such as height. A Pydro Python script is then used to “smush” together the CSF (.000) file, the .csv file, and input waterline offset measurements to create a new S57 file with correct the heights to account for the location of the IMU relative to the waterline. In CARIS this new S57 file can be exported as a .hob file to be tide corrected using CARIS Notebook.

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, buoy's 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 on 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 "leveling" (aka eyeballing) during traditional shoreline, 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 CSF 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, CARIS Notebook, Bathy DataBASE, and Plot Composer now supports feature flags previously available only in Pydro. All feature flagging can now be accomplished in CARIS Notebook while Pydro used for generating reports and performing QC.

Features are selected for investigation by HSD OPS based on distance from MHW. Project Instructions require that “All features with attribute asgnmt populated with 'Assigned' shall be verified even if they are inshore of NALL.”

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

Bottom sample data was not acquired.

C.9 Other Data

Data Acquisition Methods and Procedures

No additional data were acquired.

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. After successful testing of the Charlene processing pipeline conducted during the 2017 field season, Charlene was adopted as the official processing method for the current field season. Charlene allows the user to:

1. Perform verification of raw data
2. Build deliverable directory structure
3. Transfer and verify raw data
4. Process MBES and SSS data with 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. In less than 20m of water, any feature where the most probable accurate sounding is shoaler than the CUBE surface by greater than one half the allowable error under IHO S-44 Order 1 is considered inadequately captured by the CUBE surface. In greater than 20m of water, this allowable error is expanded to the full Order 1 error allowance at that depth. By the criteria above, if a sounding is eligible for designation it is not necessarily implied that a sounding must be designated. 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 2 included as part of Pydro XL contains the tool "Detect holidays" which now largely automates the identification of holidays in bathymetry data sets. A user selected grid is scanned, and any empty grid nodes ("holes") surrounded by populated nodes are identified. Holidays in VR grids are flagged according to the specifications found in the 2018 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 2 included as part of Pydro XL 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 this project 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 2018 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 (April 2018 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
Benjamin K. Evans, CDR/NOAA	Commanding Officer NOAA Ship Rainier	03/04/2019	Digitally signed by EVANS.BENJAMIN.K.1237217094 Date: 2019.03.05 10:58:00 -08'00'
James B. Jacobson	Chief Survey Technician NOAA Ship Rainier	03/04/2019	JACOBSON.JAMES.BRYAN.1269664017 I am the author of this document 2019.03.04 11:32:37 -08'00'
Hadley A. Owen, LT/NOAA	Field Operations Officer NOAA Ship Rainier	03/04/2019	Digitally signed by OWEN.HADLEY.ANNE.1410967070 Date: 2019.03.04 22:36:33 Z

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	RA Wiring Diagram_2018_generic EM2040 launch.pdf
Sound Speed Sensor Calibration	SBE 19 0281.pdf SBE 19plus 4039.pdf SBE 19plus 4114.pdf SBE 19plus 4306.pdf SBE 19plus 4343.pdf SBE 19plus 4676.pdf SBE 19plus 4778.pdf SBE 19plus V2 7530.pdf 2018 SVP 70 Calibration Certificates.pdf AML 008565.pdf
Vessel Offset	2801 & 2802 ReportWITHimages.pdf NOAA_2803.pdf NOAA_2804.pdf CFR 83 Ship Survey Report Rev A Survey.pdf 2018_WaterLine_Loading.pdf
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