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

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	OPR-L397-RA-17
Time Frame:	October - November 2017

LOCALITY

State(s):	California
General Locality:	Channel Islands National Marine Sanctuary, and Offshore of Morro Bay

2017

CHIEF OF PARTY
CDR Benjamin K. Evans, NOAA

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Date:

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Data Acquisition and Processing Report

NOAA Ship *Rainier*
Chief of Party: CDR Benjamin K. Evans, NOAA
Year: 2017
Version: 12.12
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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 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 Offset Verification	*Date*	2017-09-13
	Method	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 M/V IMU, and the POS M/V 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.

Figure 2: Rainier survey launch RA3 (2803)

A.1.3 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 Offset Verification	*Date*	2017-09-12
	Method	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 M/V IMU, and the POS M/V 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.

Figure 3: Rainier survey launch RA4 (2801)

A.1.4 RA5 (WZ2575)

<table>
<tr><td>Vessel Name</td><td colspan="2">RA5 (WZ2575)</td></tr>
<tr><td>Hull Number</td><td colspan="2">2802</td></tr>
<tr><td>Description</td><td colspan="2">Aluminum hull Jensen survey launch</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>8.8 meters</td></tr>
<tr><td>Beam</td><td>3.7 meters</td></tr>
<tr><td>Max Draft</td><td>1.1 meters</td></tr>
<tr><td rowspan="2">Most Recent Full Static Survey</td><td>Date</td><td>2008-03-31</td></tr>
<tr><td>Performed By</td><td>National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch</td></tr>
<tr><td rowspan="2">Most Recent Partial Offset Verification</td><td>Date</td><td>2017-09-12</td></tr>
<tr><td>Method</td><td>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 M/V IMU, and the POS M/V 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.</td></tr>
</table>

Figure 4: Rainier survey launch RA5 (2802)

A.1.5 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 Offset Verification	*Date*	2017-09-13
	Method	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 M/V IMU, and the POS M/V 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.

Figure 5: Rainier survey launch RA6 (2804)

A.1.6 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 6: Rainier survey skiff RA7 (1907)

A.1.7 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 7: Rainier survey skiff RA8 (1905)

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg Model EM710

Manufacturer	Kongsberg
Model	Model EM710

<table>
<tr><td>Description</td><td>S221 (Rainier) is equipped with a hull-mounted Kongsberg EM 710, 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.</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td rowspan="6">S221</td><td>Component</td><td>Processor</td><td>Receiver</td><td>Transducer</td></tr>
<tr><td>Model Number</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Serial Number</td><td>0356</td><td>218</td><td>unknown</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>N/A</td><td>70-100 khz</td></tr>
<tr><td>Calibration</td><td>2017-12-12</td><td>2017-12-12</td><td>2017-12-12</td></tr>
<tr><td>Accuracy Check</td><td>2017-12-12</td><td>2017-12-12</td><td>2017-12-12</td></tr>
</table>
</td></tr>
</table>

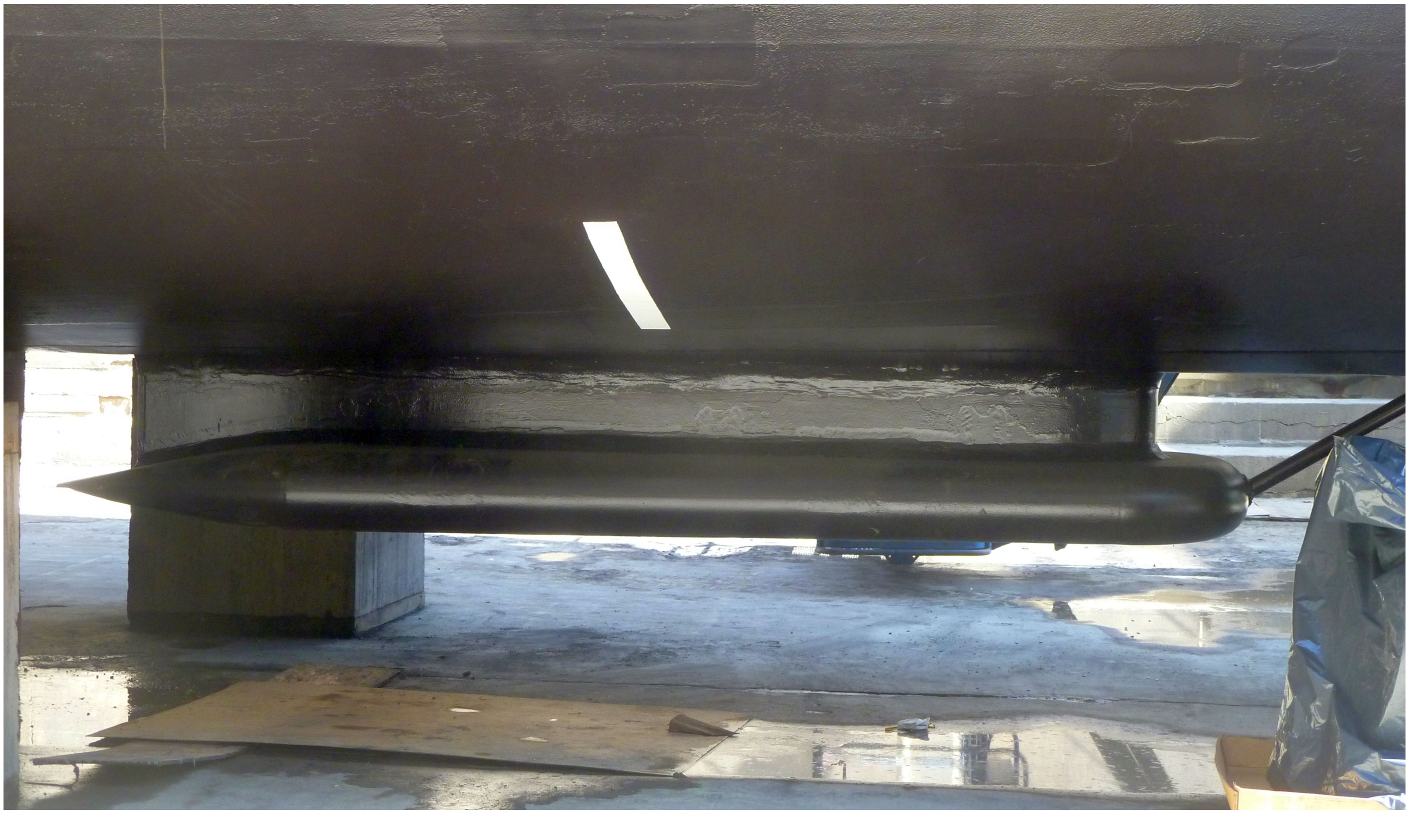

Figure 8: Kongsberg EM710 sonar transducer housing on Rainier (S221).

A.2.1.2 Kongsberg EM 2040 (07 version)

Manufacturer	Kongsberg
Model	EM 2040 (07 version)
Description	The Kongsberg EM 2040-07 consists of four units, a transmit transducer, a receive transducer, a processing unit, and a workstation. The EM 2040 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 EM 2040 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.

Inventory	*2801*	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM 2040-07	EM 2040-07	EM 2040-07
		Serial Number	40130	257	367
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2017-09-14	2017-09-14	2017-09-14
		Accuracy Check	2017-09-17	2017-09-17	2017-09-17
	2802	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM 2040-07	EM 2040-07	EM 2040-07
		Serial Number	40129	256	373
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2017-09-14	2017-09-14	2017-09-14
		Accuracy Check	2017-09-18	2017-09-18	2017-09-18
	2803	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM 2040-07	EM 2040-07	EM 2040-07
		Serial Number	40125	262	363
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2017-09-16	2017-09-16	2017-09-16
		Accuracy Check	2017-09-18	2017-09-18	2017-09-18
	2804	*Component*	Processing unit	Transmit transducer	Receive transducer
		Model Number	EM 2040-07	EM 2040-07	EM 2040-07
		Serial Number	40126	244	366
		Frequency	n/a	200-400 kHz	200-400 kHz
		Calibration	2017-09-15	2017-09-15	2017-09-15
		Accuracy Check	2017-09-19	2017-09-19	2017-09-19

Figure 9: The Kongsberg EM 2040-07 mounted on survey launch 2803.

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

A.3 Manual Sounding Equipment

A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Horizontal and Vertical Control Equipment

A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.4.4 Levels

No levels were utilized for data acquisition.

A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

A.5 Positioning and Attitude Equipment

A.5.1 Positioning and Attitude Systems

A.5.1.1 Applanix POS MV V5

Manufacturer	Applanix
Model	POS MV V5
Description	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 launch crew 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.

Inventory	*S221*	*Component*	PCS	IMU
		Model Number	POS/MV 320 V5	LN200
		Serial Number	7273	535
		Calibration	2017-04-13	2017-04-13
	2801 (RA4)	*Component*	PCS	IMU
		Model Number	POS/MV 320 V5	LN200
		Serial Number	7264	693
		Calibration	2017-09-17	2017-09-17
	2802 (RA5)	*Component*	PCS	IMU
		Model Number	POS/MV 320 V5	LN200
		Serial Number	7162	694
		Calibration	2017-09-18	2017-09-18
	2803 (RA3)	*Component*	PCS	IMU
		Model Number	POS/MV 320 V5	LN200
		Serial Number	7272	334
		Calibration	2017-09-16	2017-09-16
	2804 (RA6)	*Component*	PCS	IMU
		Model Number	POS/MV 320 V5	LN200
		Serial Number	7274	355
		Calibration	2017-09-15	2017-09-15

A.5.2 DGPS

A.5.2.1 Trimble Pathfinder Pro XRS

Manufacturer	Trimble
Model	Pathfinder Pro XRS
Description	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.

Inventory	*n/a*	*Component*	GPS receiver	GPS receiver
		Model Number	Pathfinder Pro XRS	Pathfinder Pro XRS
		Serial Number	0224070094	0224070154
		Calibration	2017-03-22	2017-03-22

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

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

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 Rolls-Royce Group ODIM Brooke Ocean MVP200 Moving Vessel Profiler (MVP)

<table>
<tr><td>Manufacturer</td><td>Rolls-Royce Group ODIM Brooke Ocean</td></tr>
<tr><td>Model</td><td>MVP200 Moving Vessel Profiler (MVP)</td></tr>
<tr><td>Description</td><td>Rainier is equipped with a Rolls-Royce Group ODIM Brooke Ocean 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, ODIM Brooke Ocean was contacted and provided Rainier with stainless steel sensor guards similar to those found on the MVP30.</td></tr>
<tr><td>Inventory</td><td><table><tr><td>S221 Rainier</td><td><table>
<tr><td>Component</td><td>CTD</td><td>CTD</td><td>CTD</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>Micro CTD</td><td>Micro CTD</td><td>Micro CTD</td><td>Micro CTD</td></tr>
<tr><td>Serial Number</td><td>7510</td><td>8614 (spare)</td><td>7761 (spare)</td><td>7511 (spare)</td></tr>
<tr><td>Calibration</td><td>2016-04-11</td><td>2016-04-11</td><td>2016-04-11</td><td>2016-04-15</td></tr>
</table></td></tr></table></td></tr>
</table>

A.6.2 CTD Profilers

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

Manufacturer	SEA-BIRD ELECTRONICS, INC.

<table>
<tr><td>Model</td><td>SBE 19 SEACAT</td></tr>
<tr><td>Description</td><td>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.</td></tr>
<tr><td>Inventory</td><td><table>
<tr><td>Component</td><td>CTD</td></tr>
<tr><td>Model Number</td><td>SBE 19</td></tr>
<tr><td>Serial Number</td><td>192472 -0281</td></tr>
<tr><td>Calibration</td><td>2017-01-31</td></tr>
</table></td></tr>
</table>

Figure 10: 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

Manufacturer	SEA-BIRD ELECTRONICS, INC.
Model	SBE 19plus SEACAT
Description	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. One SBE 19plus SEACAT profiler, 19P-7530 (red), was inadvertently not returned to Sea-Bird for its yearly calibration. Using the 2016 calibration values, profiler 19P-7530 passed regular DQC checks with the other profilers throughout the 2017 field season. In light of these positive results, profiler 19P-7530 was used throughout the 2017 field season using 2016 calibration values.

Inventory

Component	CTD	CTD	CTD	CTD	CTD
Model Number	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)	19P-7530 (red)
Calibration	2017-01-13	2017-01-13	2017-01-13	2017-01-14	2016-01-19

Figure 11: 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

<table>
<tr><td>Manufacturer</td><td>Reson Inc.</td></tr>
<tr><td>Model</td><td>SVP 70</td></tr>
<tr><td>Description</td><td>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. 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.

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 on the SVP 70 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 and CTD casts to ensure correct operation.

No surface sound speed sensor calibrations were performed. Since the XML schema has no option for bypassing the date, 09/09/1999 was entered as a placeholder.</td></tr>
<tr><td>Inventory</td><td><table>
<tr><td rowspan="4">S221 Rainier</td><td>Component</td><td>Surface sound speed sensor</td><td>Surface sound speed sensor</td></tr>
<tr><td>Model Number</td><td>SVP 70</td><td>SVP 70</td></tr>
<tr><td>Serial Number</td><td>301302</td><td>4408373</td></tr>
<tr><td>Calibration</td><td>1999-09-09</td><td>1999-09-09</td></tr>
</table></td></tr>
</table>

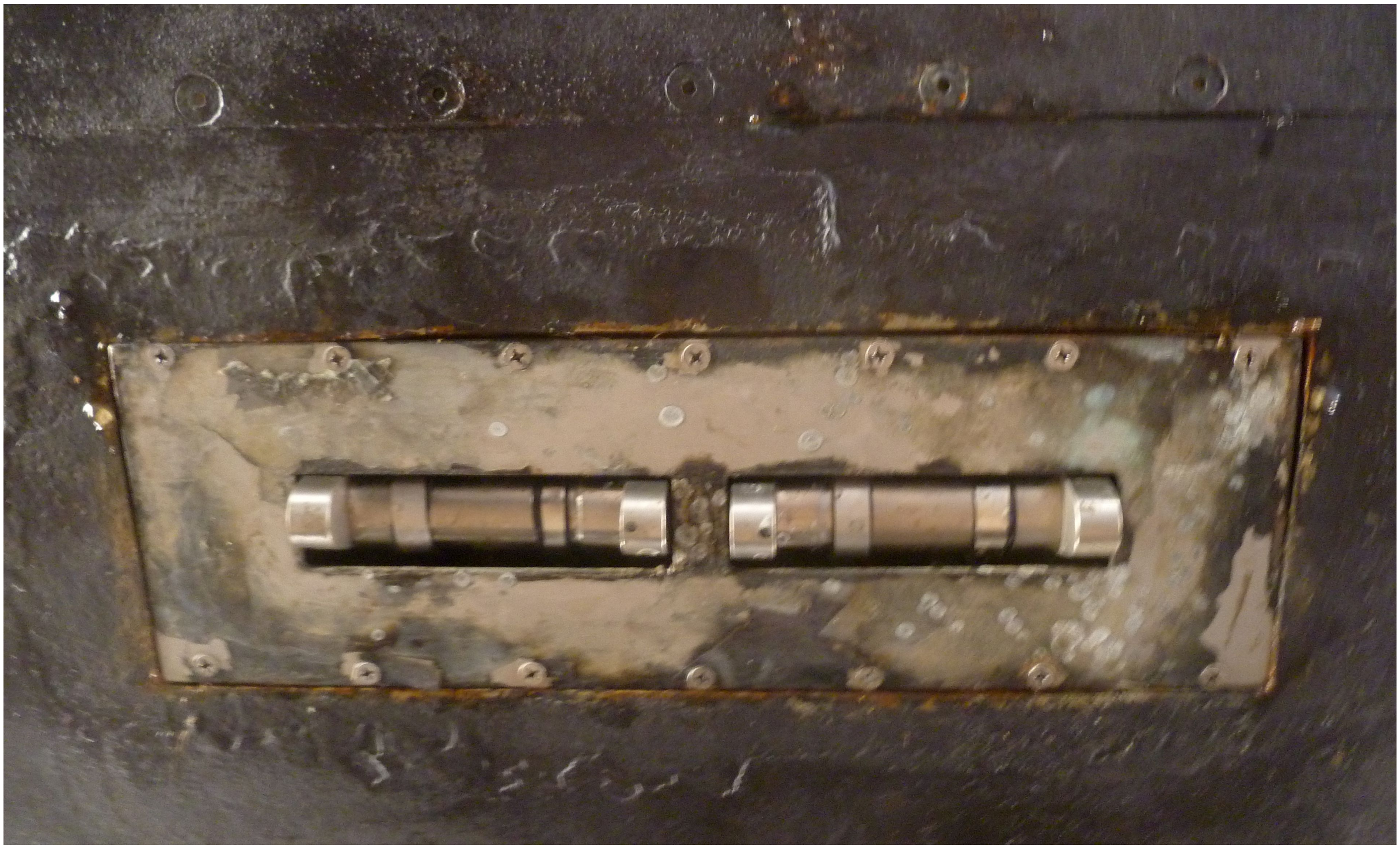

Figure 12: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.

A.6.3.2 Reson Inc. SVP 71

Manufacturer	Reson Inc.
Model	SVP 71
Description	The SVP 71 is a direct reading sound velocity probe with a sound transmission path of 125mm. The unit’s housing is constructed of a hard anodized sea water resistant aluminum and is recommended for a semi-permanent mounting where regular maintenance is possible. This sensor is mounted in close proximity to each launches’ multibeam transducers and provides real time surface sound speed values for refraction corrections. No surface sound speed sensor calibrations were performed. Since the XML schema has no option for bypassing the date, 09/09/1999 was entered as a placeholder.

Inventory	*2801*	*Component*	Surface sound speed sensor
		Model Number	SVP 71
		Serial Number	1511086
		Calibration	1999-09-09
	2802	*Component*	Surface sound speed sensor
		Model Number	SVP 71
		Serial Number	1511089
		Calibration	1999-09-09
	2803	*Component*	Surface sound speed sensor
		Model Number	SVP 71
		Serial Number	1511076
		Calibration	1999-09-09
	2804	*Component*	Surface sound speed sensor
		Model Number	SVP 71
		Serial Number	1511077
		Calibration	1999-09-09

Figure 13: A SVP 71 mounted just aft of a Kongsberg multibeam transducer on a survey launch.

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

Manufacturer	Lockheed Martin Sippican Inc., Sea-Air Systems Division
Model	XBT Deep Blue
Description	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 ±0.1ºC.

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.

Inventory	*S221 Rainier*	*Component*	XBT Launcher	Oceanographic Data Acquisition System
		Model Number	LMA3	MK21
		Serial Number	162402	10250
		Calibration	1999-09-09	1999-09-09

Figure 14: Deploying a XBT from the port-side bridge wing of Rainier.

A.7 Computer Software

A.7.1 CARIS HIPS and SIPS (x64)

Manufacturer	CARIS
Software Name	HIPS and SIPS (x64)
Version	10.3
Installation Date	2017-09-16
Use	Processing

A.7.2 CARIS BASE Editor (x64)

Manufacturer	CARIS
Software Name	BASE Editor (x64)
Version	4.2
Installation Date	2017-04-01
Use	Processing

A.7.3 CARIS Notebook

Manufacturer	CARIS
Software Name	Notebook
Version	3.1.1
Installation Date	2017-02-23
Use	Acquisition and Processing

A.7.4 Applanix POSPac MMS

Manufacturer	Applanix
Software Name	POSPac MMS
Version	8.1.6388.30062
Installation Date	2017-09-08
Use	Processing

A.7.5 Fledermaus FM Geocoder Toolbox

Manufacturer	Fledermaus
Software Name	FM Geocoder Toolbox
Version	7.7.7
Installation Date	2017-03-01
Use	Processing

A.7.6 NOAA (HSTP) Pydro XL

Manufacturer	NOAA (HSTP)
Software Name	Pydro XL

Version	17.05b
Installation Date	2017-05-23
Use	Processing

A.7.7 HYPACK, Inc. Hypack 2017

Manufacturer	HYPACK, Inc.
Software Name	Hypack 2017
Version	17.0.34.0
Installation Date	2017-04-19
Use	Acquisition

A.7.8 Kongsberg Maritime AS SIS

Manufacturer	Kongsberg Maritime AS
Software Name	SIS
Version	4.2.1
Installation Date	2017-01-11
Use	Acquisition

A.7.9 Applanix Corporation MV-POSView

Manufacturer	Applanix Corporation
Software Name	MV-POSView
Version	9.03
Installation Date	2017-03-14
Use	Acquisition

A.7.10 ODIM MVP Controller

Manufacturer	ODIM
Software Name	MVP Controller
Version	2.430
Installation Date	2015-07-16
Use	Acquisition

A.7.11 UNH/CCOM CastTime

Manufacturer	UNH/CCOM
Software Name	CastTime
Version	2013-031413
Installation Date	2014-03-01
Use	Acquisition

A.7.12 NOAA (HSTP) Velocipy

Manufacturer	NOAA (HSTP)
Software Name	Velocipy
Version	v17.11(r7485)
Installation Date	2017-06-14
Use	Acquisition

A.7.13 NOAA (HSTP) SSP Manager

Manufacturer	NOAA (HSTP)
Software Name	SSP Manager
Version	2.2.10
Installation Date	2017-12-13
Use	Acquisition and Processing

A.7.14 NOAA (HSTP) Sound Speed Manager

Manufacturer	NOAA (HSTP)
Software Name	Sound Speed Manager
Version	v.2017.6.20
Installation Date	2017-06-20
Use	Acquisition and Processing

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 GoPro unknown

Manufacturer	GoPro
Model	unknown
Description	Due to the restrictions of working in a national marine sanctuary and a desire to minimize disturbance to the seafloor, there was no bottom sample requirement for this project. However to support backscatter work with ground-truthing results Rainier made the effort to determine bottom type at discrete locations by means of a drop camera. Since the sound velocity casts which are required for MBES processing are taken all the way to the bottom, a GoPro camera in an underwater housing was attached to the cage of the CTD along with a dive light for illumination. As long as the CTD profiler hit the bottom in an upright position; an approximate determination of bottom type could be made by examination of the GoPro footage. A folder containing bottom sample images are included in the Separates section of each individual survey submission for archival purposes. A copy of the pertinent acquisition log is also include with photos to link each bottom sample site with a lat/long.

Figure 15: View of a hard rock bottom taken with a GoPro camera attached to a CTD profiler.

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 M/V 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 M/V IMU, and the POS M/V 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 M/V sensors (IMU and antennas) were entered into the POS M/V. The patch test values (the residual misalignment between the multibeam and attitude sensor) were entered into the POS M/V 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 M/V 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 POSMV 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.

The SVP offset values entered in the HVF were determined by using the appropriate surveyed values between the EM710 transmit face center and the EM710 receiver face center found in the February 25, 2014 SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY produced by the IMTEC Group. These values were then placed a rotation of reference frame spreadsheet "EM710 Coordinates and Offsets.pdf". This spreadsheet created by Sam Greenaway (HSTP) makes slight adjustments to the EM710 transmit face center and the EM710 receiver face center surveyed measurements to correct for the orientation of the ship at the time the measurements were collected.

B.1.1.1 Vessel Offset Correctors

Vessel	2801_EM2040			
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode			
Date	2017-09-14			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.203 meters	0.010 meters
		y	0.136 meters	0.010 meters
		z	0.535 meters	0.010 meters
		x2	-0.102 meters	N/A
		y2	0.036 meters	N/A
		z2	0.519 meters	N/A
	Nav to Transducer	*x*	0.203 meters	0.010 meters
		y	0.136 meters	0.010 meters
		z	0.535 meters	0.010 meters
		x2	-0.102 meters	N/A
		y2	0.036 meters	N/A
		z2	0.519 meters	N/A
	Transducer Roll	*Roll*	0.00 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">2017-09-14</td></tr>
<tr><td rowspan="15">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	2017-09-14			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	0.189 meters	0.010 meters
		y	0.135 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.116 meters	N/A
		y2	0.035 meters	N/A
		z2	0.521 meters	N/A
	Nav to Transducer	*x*	0.189 meters	0.010 meters
		y	0.135 meters	0.010 meters
		z	0.537 meters	0.010 meters
		x2	-0.116 meters	N/A
		y2	0.035 meters	N/A
		z2	0.521 meters	N/A
	Transducer Roll	*Roll*	0.00 degrees	
		Roll2	0.00 degrees	

<table>
<tr><td>Vessel</td><td colspan="4">2804_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">2017-09-14</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>0.198 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.094 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.538 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>-0.107 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>-0.006 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.522 meters</td><td>N/A</td></tr>
<tr><td rowspan="6">Nav to Transducer</td><td>x</td><td>0.198 meters</td><td>0.010 meters</td></tr>
<tr><td>y</td><td>0.094 meters</td><td>0.010 meters</td></tr>
<tr><td>z</td><td>0.538 meters</td><td>0.010 meters</td></tr>
<tr><td>x2</td><td>-0.107 meters</td><td>N/A</td></tr>
<tr><td>y2</td><td>-0.006 meters</td><td>N/A</td></tr>
<tr><td>z2</td><td>0.522 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	S221_Simrad-EM710_ICE			
Echosounder	Kongsburg Simrad EM710 0.5x1			
Date	2017-04-13			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Nav to Transducer	*x*	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Transducer Roll	*Roll*	0.00 degrees	
		Roll2	-0.31 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

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

During the determination process, a carpenter level was held level to the deck while a steel tape 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 “2017 Waterline measurements” and “2017 Waterline” reports attached to this document.

B.2.1.1 Static Draft Correctors

Vessel		2801_EM2040	2802_EM2040	2803_EM2040	2804_EM2040	S221_Simrad-EM710_ICE
Date		2017-09-14	2017-09-14	2017-09-14	2017-09-14	2017-10-04
Loading		0.025000 meters	0.025000 meters	0.025000 meters	0.025000 meters	0.025000 meters
Static Draft	*Measurement*	-0.631000 meters	-0.623000 meters	-0.626000 meters	-0.646000 meters	-4.552000 meters
	Uncertainty	0.020000 meters	0.020000 meters	0.020000 meters	0.020000 meters	0.021000 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 Rainier's 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 2017 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

DDSSM for all four Rainier launches were determined as described above and applied to all launches for the 2017 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.

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. Dynamic draft correctors may also be found in the "2017 HVF summary" included with this report.

B.2.2.1 Dynamic Draft Correctors

Vessel	2801_EM2040		2802_EM2040		2803_EM2040		2804_EM2040		S221_Simrad-EM710_ICE	
Date	2015-05-09		2015-04-13		2015-04-13		2015-04-13		2014-01-01	
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)*
	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
	1.00	-0.01	1.00	-0.01	1.00	-0.01	1.00	-0.01	1.00	-0.02
	1.50	0.00	1.50	0.00	1.50	0.00	1.50	0.00	1.50	-0.01
	2.00	0.02	2.00	0.02	2.00	0.02	2.00	0.02	2.00	0.00
	2.50	0.03	2.50	0.03	2.50	0.03	2.50	0.03	2.50	0.01
	3.00	0.05	3.00	0.05	3.00	0.05	3.00	0.05	3.00	0.03
	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05	3.50	0.05
	4.00	0.05	4.00	0.05	4.00	0.05	4.00	0.05	4.00	0.08
	4.50	0.03	4.50	0.03	4.50	0.03	4.50	0.03	4.50	0.10
	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.00	5.00	0.13
	5.50	-0.05	5.50	-0.05	5.50	-0.05	5.50	-0.05	5.50	0.15
	6.00	-0.10	6.00	-0.10	6.00	-0.10	6.00	-0.10	6.00	0.17
	6.50	-0.14	6.50	-0.14	6.50	-0.14	6.50	-0.14	6.50	0.19
	7.00	-0.20	7.00	-0.20	7.00	-0.20	7.00	-0.20	7.00	0.21
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)*
	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

As part of an ongoing upgrade effort, four Kongsberg EM2040 multibeam echo sounders were installed on Rainier’s survey launches mid-season during a ship-only offshore project. From September 12th through September 13th the systems were installed in Everett, WA and qualification of these systems occurred in Puget Sound from September 14th through September 21st.

Patch testing was conducted in Appletree Cove off of Kingston, WA. Patch test values were derived for each value after the applicable test in Qimera and / or CARIS, depending on the personnel and equipment aboard the vessel. These values were then entered into SIS before performing the next test. Once all tests were completed the values were transferred to the POS M/V, but with the opposite sign to accommodate rotating the IMU relative to the transducer rather than rotating the transducer relative to the IMU. The primary GNSS lever arm was not updated to account for this rotation directly, but the lever arm was confirmed using the POS real-time lever arm quality confirmation tool.

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.

System alignment correctors may also be found in the “2017 HVF summary” included with this report.

B.3.1.1 System Alignment Correctors

Vessel	2801_EM2040		
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode		
Date	2017-09-14		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.005 seconds
	Navigation Time Correction	0.000 seconds	0.005 seconds
	Pitch	0.00 degrees	0.10 degrees
	Roll	0.00 degrees	0.10 degrees
	Yaw	0.00 degrees	0.20 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	2017-09-14		
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	0.00 degrees	0.10 degrees
	Roll	0.00 degrees	0.10 degrees
	Yaw	0.00 degrees	0.20 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	2017-09-14

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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	2017-09-14

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	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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	2803_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2017-09-14

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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	2017-09-14

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	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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	2804_EM2040
Echosounder	Kongsberg Simrad EM2040 300kHz 0.5x1_Normal Mode
Date	2017-09-14

Patch Test Values

	Corrector	*Uncertainty*
Transducer Time Correction	0.000 seconds	0.005 seconds
Navigation Time Correction	0.000 seconds	0.005 seconds
Pitch	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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	2017-09-14

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	0.00 degrees	0.10 degrees
Roll	0.00 degrees	0.10 degrees
Yaw	0.00 degrees	0.20 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>S221_Simrad-EM710_ICE</td></tr>
<tr><td>Echosounder</td><td>Kongsburg Simrad EM710 0.5x1</td></tr>
<tr><td>Date</td><td>2016-06-27</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>0.014 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.07 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.07 degrees</td></tr>
<tr><td>Yaw</td><td>0.00 degrees</td><td>0.04 degrees</td></tr>
<tr><td>Pitch Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
</table>
</td></tr>
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<tr><td>Patch Test Values (Transducer 2)</td><td>
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<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.014 seconds</td></tr>
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C Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

For both the Rainier’s Kongsberg EM 710 and the launches Kongsberg EM 2040 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.

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 SWMB 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.
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.

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 launches 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.

New to the 2017 field season, Variable Resolution (VR) grids are now the final surface deliverable. Due to both a lack of optimization of the “new” of VR surfaces in in Caris and older processing machines, Rainier found it difficult to utilize VR grids directly as products of night-processing or for cleaning data. Caris bogged down when trying to scroll about a VR surface to such a point that the decision was made to process the using the individual surface of the appropriate resolutions and only generate the VR surface after the data was “clean” and being prepared 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

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

New to the 2017 field season, Hydrographic Surveys Technical Directive 2017-2 provided approval and guidance for the creation and submission of variable resolution bathymetric grids using CARIS HIPS and SIPS software. This directive also 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 2017 surveys.

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

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

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

Although Rainier experimented with both depth-based and density-based VR surfaces early in the field season, depth-based surfaces became the preferred method used by the start of work on project OPR-L397-RA-17 and all VR surfaces submitted for this project are of the depth-based variety.

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 Hydrographic Surveys Technical Directive 2017-2. 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 EM 2040s and Rainier's EM 710.

Data Processing Methods and Procedures

Rainier began the field season with no requirement for the creation and submission of processed multibeam backscatter data. This changed with Hydrographic Surveys Technical Directive 2017-4 (Processed Backscatter) dated August 2, 2017 which requires full backscatter processing starting with the Cold Bay project. Beginning with this project, Rainier processed and submitted backscatter mosaics as part of the regular data submission package.

Following acquisition, backscatter data is processed by using the program FM Geocoder Toolbox (FMGT) and following the subsequent 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.

-Lines are imported into FMGT. One mosaic is created per boat and frequency. So, if one boat had worked both 200kHz and 400kHz, 2 mosaics are created; one for each frequency.

-Create a mosaic. Any crosslines not needed in the mosaic are deselected. The backscatter mosaics should be kept under 200 MB to keep the program from crashing. Export type is set as grayscale GeoTIFF.

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

Real-Time Differential GPS:

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.

For the 2017 field season, all POS/MV systems are configured to receive WAAS correctors.

Real Time Position and Attitude Acquisition:

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 individually by each launch 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. 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 ‘50 Hz’. It is also important not log through UTC Midnight on Saturdays, the end of the GPS week. In the event that a line would cross over UTC Midnight, Hypack/Hysweep logging and POS file logging is stopped and a new POS file with a new day number is started after 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 three methods available in order of preference are 1) Smart Base, 2) Single Base, and finally 3) Precise Point Positioning (PPP).

New to the 2017 field season 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.

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:

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. 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) version 8.1.6 software. All SBET/RMS files are created in POSPac MMS 8.1 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.

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.

The favored method of processing raw POS MV data from launches requires input from nearby semi-permanent shore stations. 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.

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

Initial base station processing requires:

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

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

• OPUS reference frame and format -- Once the RINEX file size is reasonable (under 7mb), go to the OPUS website at: http://www.ngs.noaa.gov/OPUS. At the OPUS site the user is given the option to choose the new IGS08 reference 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 stepis 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.

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.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

Real-Time Differential GPS:

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.

For the 2017 field season, all POS/MV systems are configured to receive WAAS correctors.

Real Time Position and Attitude Acquisition:

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 individually by each launch 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. 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 ‘50 Hz’. It is also important not log through UTC Midnight on Saturdays, the end of the GPS week. In the event that a line would cross over UTC Midnight, Hpack/Hysweep logging and POS file logging is stopped and a new POS file with a new day number is started after UTC midnight.

Base Station Acquisition:

If no local CORS network is available, Rainier will install at least one GPS base station during hydrographic operations in the project area. Base station sites are selected to be centrally located within the project area to provide maximum coverage, ideally within the Applanix recommended 20 kilometer range of any POS/MV data collected. Base station sites are also chosen for both clear lines of sight to either survey launches or the ship for easy data downloads in addition to a clear horizon to maximize the number of GPS satellites observed.

Each station consists of a GNSS reference receiver with internal memory interfaced with an Ethernet radio all sealed in a watertight Pelican plastic case. A UHF antenna connected to the Ethernet radio provides for remote daily download of the GNSS data stored in the receiver. These files are retained as raw data and stored in a ‘Base_Station_Data’ folder under them appropriate project on a day by day basis.

The Trimble NetR5 and NetR9 Global Navigation Satellite System (GNSS) reference station receivers used by Rainier collect data in raw .T01 or .T02 format. Data collection parameters are configured as per the “TRIMBLE NetR9 SETUP” document in Appendix IV of the FPM.

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 three methods available in order of preference are 1) Smart Base, 2) Single Base, and finally 3) Precise Point Positioning (PPP).

New to the 2017 field season 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.

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

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. 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) version 8.1.6 software. All SBET/RMS files are created in POSPac MMS 8.1 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.

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.

The favored method of processing raw POS MV data from launches requires input from nearby semi-permanent shore stations. 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.

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

Initial base station processing requires:

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

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

• OPUS reference frame and format -- Once the RINEX file size is reasonable (under 7mb), go to the OPUS website at: http://www.ngs.noaa.gov/OPUS. At the OPUS site the user is given the option to choose the new IGS08 reference 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.

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) or the Rolls-Royce Moving Vessel Profiler (MVP200) to acquire sound speed data.

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.

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 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.

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'.

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed values are measured by a SVP 70 on Rainier and SVP 71 probes 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.

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 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 71 fixed-mount sound velocity probe is affixed to launches 2801 2802, 2803 and 2804 to provide correctors for the flat faced EM 2040. A Reson SVP 70 is mounted on Rainier to provide correctors for the EM 710. The Reson SVP 71 velocity probe has a published accuracy of 0.15 m/s while the SVP 70 has a published accuracy of 0.05 m/s.

ERZT SEP Uncertainty Calculation

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 is no uncertainty values associated with it.

Rainier, with consultation from HST 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.

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.

TPU values may also be found in the “2017 HVF summary” included with this report.

C.6.2 Uncertainty Components

A Priori Uncertainty

Vessel		2801_EM2040	2802_EM2040	2803_EM2040	2804_EM2040	S221_Simrad-EM710_ICE
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees	0.02 degrees
Navigation Sensor		1.00 meters	1.00 meters	1.00 meters	1.00 meters	1.00 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 4m 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 16: Survey skiff RA7 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.

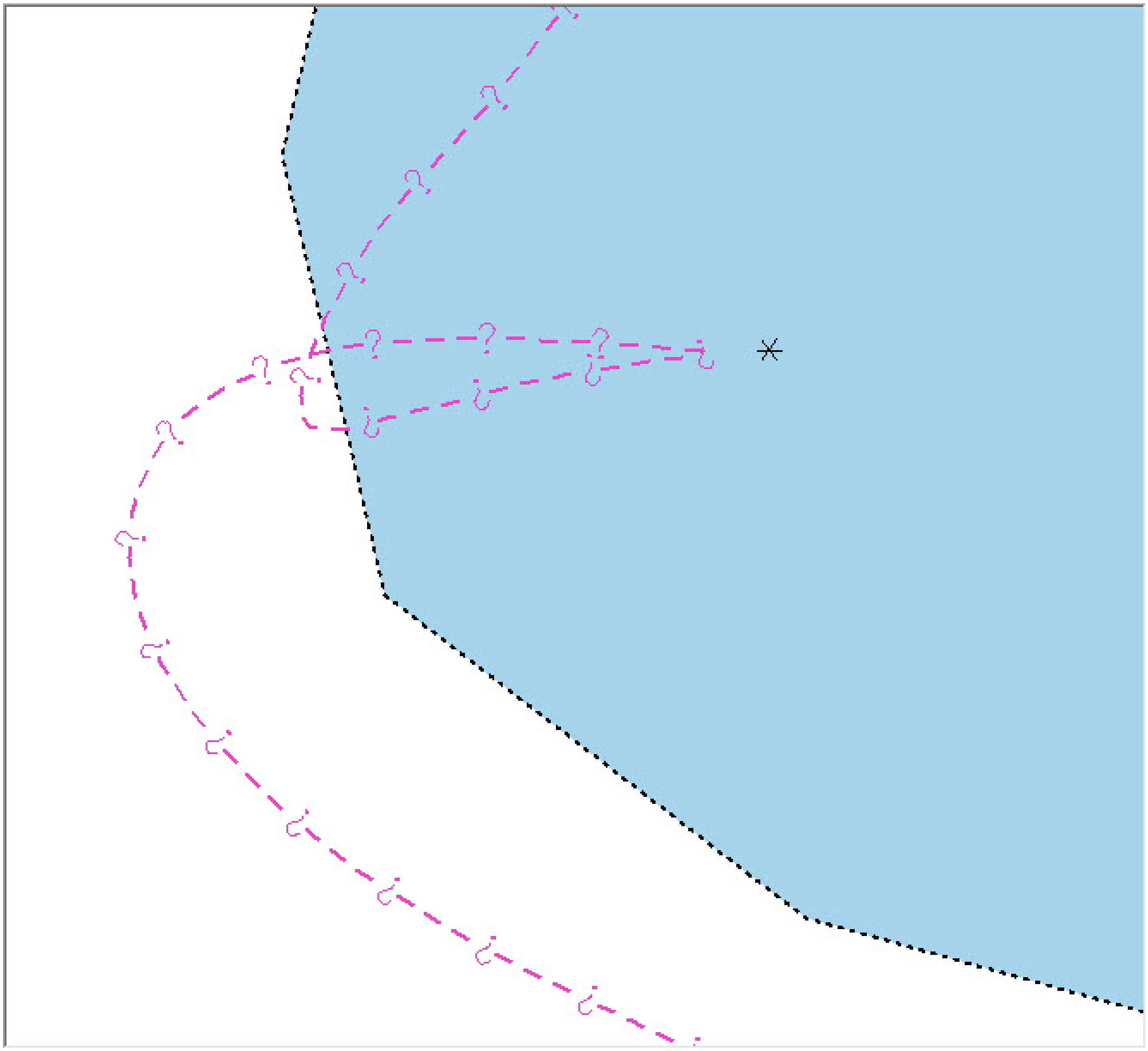

Figure 17: The magenta track-line collected in the field with a skiff and CARIS Notebook used to position a new rock.

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.

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 crewmembers, 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.

New to night processing for the 2017 field season is Charlene, the automated data processor. Initial testing of the Charlene processing pipeline was conducted on select sheets in Northern Kodiak project. Charlene was adopted as the official processing method for all data collected after the Cold Bay project.

Charlene is an automated night processing and data transfer tool developed by NOAA's Office of Coast Survey in early 2017. Night processing includes all of those tasks in between raw data collection and a final daily product that occur each night on our hydrographic vessels. Charlene 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. 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. To ensure that these features are properly represented, the shoalest point is flagged “designated” in CARIS. 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 is single resolution grids are flagged according to the specifications found in the 2017 NOAA NOS Hydrographic Survey Specifications and Deliverables. Holidays in VR grids are flagged according to the specifications found in NOAA HTD 2017-2 “Caris Variable Resolution Grids”.

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:

• The Depth layer plotted as a distribution (entitled “Depth Distribution”), the Density layer is plotted as a distribution (entitled “Object Detection Coverage”).
• The Density layer plotted as a distribution (entitled “Object Detection Coverage”).
• Density plotted against the corresponding Depth of the node (entitled “Node Depth vs. Sounding Density”).
• TVU QC plotted as a distribution (entitled “Uncertainty Standards”).
• TVU QC plotted against the corresponding Depth of the node (entitled “Node Depth vs. TVU QC”).
• Only for Variable Resolution grids, a histogram with the percentage of nodes at the prescribed resolution is created. This histogram can be used to evaluate whether “95% of all surface nodes have a resolution equal to or smaller than the coarsest allowable resolution for the node depth” as required by NOAA HTD 2017-2.

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

Imagery data integrity and quality management were not conducted for this survey.

List of Appendices:

Mandatory Report	*File*
Vessel Wiring Diagram	2017%202801%20%28RA4%29%20Wiring%20Diagram.pdf
	2017%202802%20%28RA5%29%20Wiring%20Diagram.pdf
	2017%202803%20%28RA3%29%20Wiring%20Diagram.pdf
	2017%202804%20%28RA6%29%20Wiring%20Diagram.pdf
	2017%20S221%20%28RAINIER%29%20Wiring%20Diagram.pdf
Sound Speed Sensor Calibration	SBE%2019%20C0281%2020Jan17.pdf
	SBE%2019%20C0281%2031Jan17.pdf
	SBE%2019%20P0281%2016Jan17.pdf
	SBE%2019%20T0281%2020Jan17.pdf
	SBE%2019%20T0281%2031Jan17.pdf
	SBE%2019plus%20C4039%2013Jan17.pdf
	SBE%2019plus%20P4039%2011Jan17.pdf
	SBE%2019plus%20T4039%2013Jan17.pdf
	SBE%2019plus%20C4114%2013Jan17.pdf
	SBE%2019plus%20P4114%2011Jan17.pdf
	SBE%2019plus%20T4114%2013Jan17.pdf
	SBE%2019plus%20C4306%2013Jan17.pdf
	SBE%2019plus%20P4306%2011Jan17.pdf
	SBE%2019plus%20T4306%2013Jan17.pdf
	SBE%2019plus%20C4343%2009Feb17.pdf
	SBE%2019plus%20C4343%2014Jan17.pdf
	SBE%2019plus%20P4343%2011Jan17.pdf
	SBE%2019plus%20T4343%2009Feb17.pdf
	SBE%2019plus%20T4343%2014Jan17.pdf
	SBE%2019plus%20V2%20C7530%2019Jan17.pdf
	SBE%2019plus%20V2%20P7530%2017Jan17.pdf
	SBE%2019plus%20V2%20T7530%2019Jan17.pdf
Vessel Offset	2017_GPS_Offsets.pdf
	2017_GPS_Offsets_Measurements.pdf
	2017_Sonar_Offsets.pdf
	2017_Sonar_Offsets_Measurements.pdf

Mandatory Report	***File***
	S221_POS_GPS_Ant.pdf
	CFR%2083%20Ship%20Survey%20Report%20Rev%20A%20Survey.pdf
	EM710%20Coordinates%20and%20Offsets.pdf
Position and Attitude Sensor Calibration	2017%20POS-MV%20Calibration.pdf
Echosounder Confidence Check	2017%20Reference%20Surface%20Comparison.pdf
Echosounder Acceptance Trial Results	RA_Ice_TxRx_2014-final.pdf
	Rainier_Launch_EM2040_Acceptance.pdf

E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were followed during the 2017 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 2017 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	05/24/2018	Digitally signed by EVANS.BENJAMIN.K.1237217094 Date: 2018.06.22 08:59:21 -07'00'
James B. Jacobson	Chief Survey Technician NOAA Ship Rainier	05/24/2018	JACOBSON.JAMES.BRYAN.1269664017 I am the author of this document 2018.05.29 09:10:20 -07'00'
Scott E. Broo, LT/NOAA	Field Operations Officer NOAA Ship Rainier	05/24/2018	Digitally signed by BROO.SCOTT.EDWARD.1396599976 Date: 2018.06.21 10:01:37 -08'00'