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Data Acquisition & Processing Report

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LOCALITY

State(s):	California Oregon Washington
General Locality:	Offshore California, Oregon and Washington & Offshore South-Central California

2018

CHIEF OF PARTY
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Date:

Table of Contents

A. System Equipment and Software........ 1
A.1 Survey Vessels........ 1
A.1.1 NOAA Ship Rainier (WTEF)........ 1
A.2 Echo Sounding Equipment........ 2
A.2.1 Multibeam Echosounders........ 3
A.2.1.1 Kongsberg Model EM710........ 3
A.2.2 Single Beam Echosounders........ 4
A.2.3 Side Scan Sonars........ 4
A.2.4 Phase Measuring Bathymetric Sonars........ 4
A.2.5 Other Echosounders........ 4
A.3 Manual Sounding Equipment........ 4
A.3.1 Diver Depth Gauges........ 5
A.3.2 Lead Lines........ 5
A.3.3 Sounding Poles........ 5
A.3.4 Other Manual Sounding Equipment........ 5
A.4 Horizontal and Vertical Control Equipment........ 5
A.4.1 Base Station Equipment........ 5
A.4.2 Rover Equipment........ 5
A.4.3 Water Level Gauges........ 5
A.4.4 Levels........ 5
A.4.5 Other Horizontal and Vertical Control Equipment........ 5
A.5 Positioning and Attitude Equipment........ 6
A.5.1 Positioning and Attitude Systems........ 6
A.5.1.1 Applanix POS MV V5........ 6
A.5.2 DGPS........ 7
A.5.3 GPS........ 7
A.5.4 Laser Rangefinders........ 7
A.5.4.1 Laser Technology Inc. Impulse 200 LR........ 7
A.5.5 Other Positioning and Attitude Equipment........ 8
A.6 Sound Speed Equipment........ 8
A.6.1 Moving Vessel Profilers........ 8
A.6.2 CTD Profilers........ 8
A.6.3 Sound Speed Sensors........ 8
A.6.3.1 Reson Inc. SVP 70........ 8
A.6.4 TSG Sensors........ 9
A.6.5 Other Sound Speed Equipment........ 9
A.6.5.1 Lockheed Martin Sippican Inc., Sea-Air Systems Division XBT Deep Blue........ 9
A.7 Computer Software........ 11
A.8 Bottom Sampling Equipment........ 12
A.8.1 Bottom Samplers........ 12
B. System Alignment and Accuracy........ 12
B.1 Vessel Offsets and Layback........ 12
B.1.1 Vessel Offsets........ 13
B.1.1.1 Vessel Offset Correctors........ 13
B.1.2 Layback........ 13

B.2 Static and Dynamic Draft........14
B.2.1 Static Draft........14
B.2.1.1 Static Draft Correctors........14
B.2.2 Dynamic Draft........14
B.2.2.1 Dynamic Draft Correctors........15
B.3 System Alignment........15
B.3.1 System Alignment Methods and Procedures........16
B.3.1.1 System Alignment Correctors........17
C. Data Acquisition and Processing........17
C.1 Bathymetry........17
C.1.1 Multibeam Echosounder........17
C.1.2 Single Beam Echosounder........20
C.1.3 Phase Measuring Bathymetric Sonar........20
C.1.4 Gridding and Surface Generation........20
C.1.4.1 Surface Generation Overview........20
C.1.4.2 Depth Derivation........21
C.1.4.3 Surface Computation Algorithm........21
C.2 Imagery........22
C.2.1 Multibeam Backscatter Data........22
C.2.2 Side Scan Sonar........22
C.2.3 Phase Measuring Bathymetric Sonar........23
C.3 Horizontal and Vertical Control........23
C.3.1 Horizontal Control........23
C.3.1.1 GNSS Base Station Data........23
C.3.1.2 DGPS Data........23
C.3.2 Vertical Control........24
C.3.2.1 Water Level Data........24
C.3.2.2 Optical Level Data........24
C.4 Vessel Positioning........24
C.5 Sound Speed........25
C.5.1 Sound Speed Profiles........25
C.5.2 Surface Sound Speed........26
C.6 Uncertainty........26
C.6.1 Total Propagated Uncertainty Computation Methods........27
C.6.2 Uncertainty Components........30
C.7 Shoreline and Feature Data........30
C.8 Bottom Sample Data........30
C.9 Other Data........30
D. Data Quality Management........31
D.1 Bathymetric Data Integrity and Quality Management........31
D.1.1 Directed Editing........31
D.1.2 Designated Sounding Selection........32
D.1.3 Holiday Identification........32
D.1.4 Uncertainty Assessment........33
D.1.5 Surface Difference Review........33
D.1.5.1 Crossline to Mainscheme........33
D.1.5.2 Junctions........33

D.1.5.3 Platform to Platform........34
D.2 Imagery data Integrity and Quality Management........34
D.2.1 Coverage Assessment........34
D.2.2 Contact Selection Methodology........34
E. Approval Sheet........35
List of Appendices:........36

List of Figures

Figure 1: NOAA Ship Rainier (S221)........2
Figure 2: Kongsberg EM710 sonar transducer housing on Rainier (S221)........4
Figure 3: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola........9
Figure 4: Deploying a XBT from the port-side bridge wing of Rainier........11

Data Acquisition and Processing Report

NOAA Ship *Rainier*
Chief of Party: Benjamin K. Evans, CDR, NOAA
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Version: 3
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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.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Kongsberg Model EM710

S221 (Rainier) is equipped with a hull-mounted Kongsberg EM710, which operates at sonar frequencies in the 70 to 100 kHz range. The across-track swath width is up to 5.5 times water depth with a published maximum depth of more than 2000 meters. The along-track beamwidth of Rainier's configuration is ½° with a receive beam width of 1°. The maximum number of beams is 400, with dynamic focusing employed in the near field. A high density beam processing mode provides up to 400 or 200 soundings per swath by using a limited range window for the detections. The beamspacing may be set to be either equiangular or equidistant. Rainier typically collects 400 beams per ping in equidistant mode.

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

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

Figure 2: Kongsberg EM710 sonar transducer housing on Rainier (S221).

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

Rainier is outfitted with the Applanix POS MV 320 version 5. The POS MV version 5 offers a number of key new features including:

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

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

Position accuracy is displayed in real time by the POS MV software and is monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables (HSSD) were not exceeded. In addition, the POS MV software displays HDOP and the number of satellites used in position computation. Data acquisition is generally halted when an HDOP of 2.5 is exceeded or the number of satellites available drop below four. However, because positional accuracy can be maintained by the POS MV through short GPS outages with the help of the IMU, data acquisition is not halted during short periods of time when the HDOP and number of satellites used exceeded stated parameters. When using differential correctors, the POS MV generates positional data to an accuracy of 0.5-2 meters.

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

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

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

Full POSPac data are also recorded on Rainier. 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.

<table>
<tr><td>Manufacturer</td><td colspan="4">Applanix</td></tr>
<tr><td>Model</td><td colspan="4">POS MV V5</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S221</td><td>Component</td><td>PCS</td><td>IMU</td></tr>
<tr><td>Model Number</td><td>POS MV 320 V5</td><td>LN200</td></tr>
<tr><td>Serial Number</td><td>7273</td><td>535</td></tr>
<tr><td>Calibration</td><td>2018-06-08</td><td>2018-06-08</td></tr>
</table>

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

A.5.4.1 Laser Technology Inc. Impulse 200 LR

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

Manufacturer	Laser Technology Inc.		
Model	Impulse 200 LR		
Inventory	*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

No moving vessel profilers were utilized for data acquisition.

A.6.2 CTD Profilers

No CTD profilers were utilized for data acquisition.

A.6.3 Sound Speed Sensors

A.6.3.1 Reson Inc. SVP 70

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

Aboard Rainier these two sensors are mounted in close proximity to the ship's multibeam transducers and provide real time surface sound speed values for refraction corrections. Yearly calibrations of these SVP 70s are not performed since the instrument can only be removed from the ship during a dry dock, however readings from this sensor are compared to MVP, CTD and/or XBT casts to ensure correct operation.

Manufacturer	Reson Inc.			
Model	SVP 70			
Inventory	*S221 Rainier*	*Component*	Surface sound speed sensor	Surface sound speed sensor
		Model Number	SVP 70	SVP 70
		Serial Number	301302	4408373
		Calibration	N/A	N/A

Figure 3: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.

A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

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

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

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

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

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

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

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

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

Figure 4: Deploying a XBT from the port-side bridge wing of Rainier.

A.7 Computer Software

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

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

No bottom sampling equipment was utilized for data acquisition.

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

EM710

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

B.1.1.1 Vessel Offset Correctors

Vessel	S221_Simrad-EM710_ICE			
Echosounder	Kongsburg Simrad EM710 0.5x1			
Date	2018-06-08			
Offsets	*MRU to Transducer*		*Measurement*	*Uncertainty*
		x	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Nav to Transducer	*x*	1.704 meters	0.002 meters
		y	8.059 meters	0.002 meters
		z	4.601 meters	0.002 meters
		x2	1.759 meters	N/A
		y2	6.802 meters	N/A
		z2	4.600 meters	N/A
	Transducer Roll	*Roll*	0.00 degrees	
		Roll2	-0.31 degrees	

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

For Rainier, static draft is determined by direct measurement to the physical waterline. Draft measurements are taken throughout the field season any time there is major chance in the ship's draft, for example after fueling. A good time to conduct these measurements is while the ship is still inport where motion by both the ship and sea is minimized.

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

B.2.1.1 Static Draft Correctors

Vessel		S221_Simrad-EM710_ICE
Date		2018-09-25
Loading		0.025 meters
Static Draft	*Measurement*	-4.802 meters
	Uncertainty	0.021 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 lacks 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.

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.

B.2.2.1 Dynamic Draft Correctors

Vessel	S221_Simrad-EM710_ICE	
Date	2014-01-01	
Dynamic Draft	*Speed (m/s)*	*Draft (m)*
	0.00	0.00
	0.50	-0.01
	1.00	-0.02
	1.50	-0.01
	2.00	0.00
	2.50	0.01
	3.00	0.03
	3.50	0.05
	4.00	0.08
	4.50	0.10
	5.00	0.13
	5.50	0.15
	6.00	0.17
	6.50	0.19
	7.00	0.21
Uncertainty	*Vessel Speed (m/s)*	*Delta Draft (m)*
	0.08	0.01

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

EM710

As part of the upgrade to ice-hardened transducers for Rainier's EM710 system, Kongsberg service engineers attended the sea acceptance trials. During these trials, Rainier conducted MBES calibration tests for the Kongsberg EM710 installed on board. In spite of the Kongsberg multibeam system working on multiple frequencies (70-100 kHz), only one patch test is required since the system has only one transducer. The calibration procedure used follows that outlined in section 1.5.5.1 of the 2014 Field Procedures Manual. Timing, pitch and yaw bias was determined using a steep slope. Roll bias was determined using the standard flat bottom method. The patch test was independently processed in CARIS HIPS, SwathEd, SIS, and Simrad Neptune, and the consensus values entered into SIS.

As part of the annual HSRR, Rainier conducted a patch test for the EM710 multibeam system to confirm the values from the 2014 installation remained unchanged. Without zeroing out any values in SIS or the POS MV, the patch test values would be expected to be at or near zero. If the patch test results bore this out, the SIS and the POS MV values were considered confirmed and left unchanged.

Due to the peculiarities of system integration, system alignment correctors for the ship are applied in the acquisition software (SIS) rather than in CARIS by way of the HVF. In addition, over the winter the ship's acquisition system stay mounted as installed during the 2014 dry-dock rather than being removed for maintenance and safe storage over the winter and re-installed for the field season as occurs on the launches. In light of these factors, the annual determination of alignment correctors for the ship is a verification of existing values rather than a determination of new values required for the launches due to the annual re-installation of the acquisition systems.

Data was converted in CARIS HIPS using the regular HVF file which already has the heave, pitch, roll and timing values set to zero. True heave, water levels, the most recent dynamic draft, and sound velocity profiles were applied and the data merged before cleaning via Swath Editor. Biases were determined using the CARIS HIPS Calibration tool by at least 5 individual testers. The multiple values determined for each bias by individual testers were examined by a reviewer, and obvious outliers rejected before an average was determined. This average value was then applied to the bias in question and applied to the data before moving on to the next bias determination. Bias values were determined in the following order; timing, pitch, roll, and finally yaw.

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

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

B.3.1.1 System Alignment Correctors

<table>
<tr><td>Vessel</td><td colspan="3">S221_Simrad-EM710_ICE</td></tr>
<tr><td>Echosounder</td><td colspan="3">Kongsburg Simrad EM710 0.5x1</td></tr>
<tr><td>Date</td><td colspan="3">2016-06-27</td></tr>
<tr><td rowspan="10">Patch Test Values</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.03 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.03 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>0.024 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Date</td><td colspan="3">2016-06-27</td></tr>
<tr><td rowspan="10">Patch Test Values (Transducer 2)</td><td></td><td>Corrector</td><td>Uncertainty</td></tr>
<tr><td>Transducer Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Navigation Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Pitch</td><td>0.00 degrees</td><td>0.03 degrees</td></tr>
<tr><td>Roll</td><td>0.00 degrees</td><td>0.03 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>0.024 seconds</td></tr>
<tr><td>Roll Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Yaw Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
<tr><td>Heave Time Correction</td><td>0.000 seconds</td><td>0.024 seconds</td></tr>
</table>

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

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

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

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

For ship acquisition, a blended solution of line planning and real-time coverage is adopted. At the start of acquisition, a single line is drawn, which the ship navigates via Hypack. Throughout the line, the survey team notes the swath width and, based on these values, renders the subsequent survey line in such a way to provide ~10% overlap with the previous line. In this way, lines are used to minimize the number of turns and course adjustments required for the relatively un-maneuverable Rainier; while the real-time coverage is used to prevent excessive overlap or holidays based on an (ill-informed) a priori line plan.

Data Processing Methods and Procedures

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

1. Convert the "raw" SIS data to the HDCS data format.
2. Load Delayed Heave.
3. Load predicted tides.

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

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

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

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

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

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

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

It has been the experience aboard Rainier that CUBE surfaces of differing resolutions that cover the same dataset may produce widely different results. This problem can be eliminated by choosing resolution values that are even multiples. 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. CUBE surface resolution values of 8, 16 and 32 meters were chosen for the deep-water surveys encountered on these offshore projects.

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

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

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

• Subset Mode is the default tool selected due to its ability to quickly compare large numbers of soundings with adjacent or overlapping data for confirmation or rejection. Subset mode also excels with the assessment of possible features, disagreement between overlapping lines, and crossline comparison. Subset Mode can be used to visually enhance patterns and anomalies in CUBE surfaces.
• Swath Editor is useful for burst noise, multipath, and other "gross fliers" which are specific to a particular line or lines, and most easily removed in this mode. Additionally, when it was felt that the quality of the data was reduced due to environmental conditions such as rough seas or extreme variance in sound velocity, data were filtered on a line by line basis to a lesser swath width to ensure data quality.
• Both modes (but particularly Swath Editor) are used as a training aid to help novices learn how the various

sonars operate, and provide feedback to the acquisition process.

With the advent of CUBE-based processing, it has become possible to adjust the final bathymetric surface directly by selecting the correct hypothesis to use. Although this method is available, it is not permitted and it is standard practice on Rainier to clean soundings in the traditional method until the CUBE algorithm selects the correct hypothesis.

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

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

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

Although the 2018 HSSD still contains provisions for single-resolution deliverables, Hydrographic Surveys Technical Directive 2017-2 expressed the desire that all NOAA field units should use variable resolution surfaces to the greatest extent possible. Rainier submitted VR surfaces as the deliverable for all 2018 surveys.

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

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

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

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

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

Although Rainier has experimented with both depth-based and density-based VR surfaces, depth-based surfaces became the preferred method and all VR surfaces submitted for the 2018 field season are of the depth-based variety. It has been Rainier’s observations that a Calder-Rice density-based surface is ~7 times larger than a depth ranges surface covering the same area. Depth-based surfaces also appear superior in terms of processing time and ease of use in CARIS.

C.1.4.2 Depth Derivation

Final depth generation has not been a part of Rainier's processing pipeline ever since CUBE surfaces became the final deliverable.

C.1.4.3 Surface Computation Algorithm

VR surfaces created aboard Rainier adhere to a set of recommended estimation parameters and mandatory population method parameters as documented in 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 Rainier's EM710.

Data Processing Methods and Procedures

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

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

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

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

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

-When creating a mosaic, any crosslines not needed in the mosaic is deselected. 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

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

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

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

The WAAS specification requires it to provide a position accuracy of 7.6 meters (25 ft) or better (for both horizontal and vertical measurements), at least 95% of the time. Actual performance measurements of the system at specific locations have shown it typically provides better than 1.0 meter horizontally and 1.5 meters vertically throughout most of the contiguous United States and large parts of Canada and Alaska. In more remote regions of Alaska, values range between 2 and 6 meters horizontally.

All POS MV systems in use on Rainier are configured to receive WAAS correctors.

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

No processing of individual DGPS correctors occurs in Rainier's processing pipeline.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

All real time position and attitude data are acquired using POSView and post processed using POSPac MMS. For further details on individual processing methodology, refer to the HVCR of the appropriate project.

The POS MV .000 files are collected by Rainer daily, beginning at least five minutes before the collection of bathymetric data and ending at least five minutes after the conclusion of bathymetric data collection. While conducting 24 hours operations, the POS file is usually broken up into 12 hour pieces to facilitate processing and prevent potential data loss. Logging is started by opening the MV-POSView window and selecting "Ethernet Realtime…" from the Logging menu. In the Ethernet Realtime Output Control window only the following message groups are selected: 3, 7, 20, 102, 111 and 113. The Output Control rate is also set to '50 Hz'.

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

Data Processing Methods and Procedures

Rainier utilizes Post Processed Kinematic (PPK) methods for the horizontal positioning of bathymetric data. The exact method selected is based upon the availability, or lack thereof, of Continually Operating Reference Stations (CORS) near the project area. The four methods available in order of preference are 1) PP-RTX, 2) Smart Base, 3) Single Base, and finally 4) Precise Point Positioning (PPP). For both projects OPR-M367-RA-18 and OPR-L373-RA-18, Post-Processed Real Time Extended (PP-RTX) was exclusively used to post-process positioning data.

PP-RTX:

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

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

SBETs are applied in CARIS by loading both the SBET files and error data files in smrmsg format. For every SBET file generated during PP-RTX 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.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

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.

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 survey also monitors the real-time display of the Reson SVP 70 for changes of 2 m/s or greater in the surface sound velocity indicative of the need for a new cast.

Data Processing Methods and Procedures

For XBT:

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

C.5.2 Surface Sound Speed

Data Acquisition Methods and Procedures

Surface sound speed values are measured by a SVP 70 on Rainier and 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 (if applicable) is unique for each project area and typically provided in Appendix II of the Hydrographic Survey Project Instructions, Water Level Instructions. In section 1.3.1.1 of the Water Level Instructions, Tide Component Error Estimation, the tidal error contribution to the total survey error budget is provided at the 95% confidence level, and includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. Since this tidal error value is given for two sigma, the value must be divided by 1.96 before it can be entered into CARIS (which expects a one sigma value). If TCARI grids are assigned to the project area, this value is set at 0.0 since TCARI automatically calculates the error associated with water level interpolation and incorporates it into the residual/harmonic solutions.

• Measured sound speed value error ranges from 0.5 to 4 m/s, dependent on temporal/spatial variability. 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. A redundant pair of Reson SVP 70s is mounted on Rainier to provide correctors for the EM710. The Reson SVP 70 has a published accuracy of 0.05 m/s.

• When a sheet has the requirement to acquire survey data vertically referenced to the ellipsoid, and converted to MLLW using VDatum, the separation uncertainty value replaces the tide zoning value in the calculation of TPU. The separation uncertainty value is included in the Vertical Control Requirements section of the Project Instructions.

ERZT SEP Uncertainty Calculation (if applicable)

When a project has a requirement to acquire survey data vertically-referenced to the ellipsoid and no VDatum is supplied, 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 HSTB 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 EM710 were recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.

TPU Calculation Methods

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

Source of TPU Values

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

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

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

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

C.6.2 Uncertainty Components

A Priori Uncertainty

Vessel		S221_Simrad-EM710_ICE
Motion Sensor	*Gyro*	0.02 degrees
	Heave	5.00% 0.05 meters
	Roll	0.02 degrees
	Pitch	0.02 degrees
Navigation Sensor		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 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

Shoreline and feature data was not acquired.

C.8 Bottom Sample Data

Bottom sample data was not acquired.

C.9 Other Data

Data Acquisition Methods and Procedures

No additional data were acquired.

Data Processing Methods and Procedures

Initial data processing at the end of each survey day is the responsibility of the Night Processing Team, or Launch Crew if no Night Processing Team is assigned. The Night Processing Team is typically composed of two crew members, one with at least a year's experience, and one junior member in training. Daily processing produces a preliminary product in which all gross data problems have been identified and/or removed, and thus can be used by the Survey Team to plan the next day's operations. The Night Processors complete a data pass down log to inform the Survey Manager and FOO of any notable features or systematic problems in the day's data. In the case of ship acquisition, the survey watch active at UTC midnight may be tasked to process the previous day of ship hydro in lieu of a team of dedicated night processors.

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

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

1. Perform verification of raw data
2. Build deliverable directory structure
3. Transfer and verify raw data
4. Process MBES and SSS data with CARIS Batch Processor
5. Generate SBETs with POSPac Batch
6. Use NOAA tools like AutoQC, QCTools and TCARI

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

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

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

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

D.1.2 Designated Sounding Selection

On occasion, the resolution of the CUBE surface may not be sufficient to capture the high point of a feature. In less than 20m of water, any feature where the most probable accurate sounding is shoaler than the CUBE surface by greater than one half the allowable error under IHO S-44 Order 1 is considered inadequately captured by the CUBE surface. In greater than 20m of water, this allowable error is expanded to the full Order 1 error allowance at that depth. By the criteria above, if a sounding is eligible for designation it is not necessarily implied that a sounding must be designated. In general, sounding designation solely to adjust the surface is frowned upon and rarely used. Rather, sounding designation is used only when those soundings are of critical importance.

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

D.1.3 Holiday Identification

QC Tools 2 included as part of Pydro XL contains the tool "Detect holidays" which now largely automates the identification of holidays in bathymetry data sets. A user selected grid is scanned, and any empty grid nodes ("holes") surrounded by populated nodes are identified. Holidays in VR grids are flagged according to the specifications found in the 2018 NOAA NOS Hydrographic Survey Specifications and Deliverables.

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

D.1.4 Uncertainty Assessment

QC Tools 2 included as part of Pydro XL contains the tool "Grid QA" which now largely automates the computation of grid statistics to ensure compliance to uncertainty and density requirements. The Depth, Uncertainty, Density (if available), and a computed Total Vertical Uncertainty (TVU) QC layer (optional) are used to compute particular statistics shown as a series of plots. The TVU QC is either given to the program in the grid input, or calculated on-the-fly. It is determined by a ratio of uncertainty to allowable error per NOAA and IHO specification.

Grid QA outputs the following plots:

• 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 2018 HSSD.

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

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

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

D.1.5.2 Junctions

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

D.1.5.3 Platform to Platform

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

D.2 Imagery data Integrity and Quality Management

D.2.1 Coverage Assessment

Side Scan Sonar:

No SSS data were collected for this project.

Backscatter:

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

D.2.2 Contact Selection Methodology

No SSS data were collected for this project and therefore no contacts were selected.

E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were followed during the 2018 field season. All operations were conducted in accordance with the Office of Coast Survey Field Procedures Manual (April 2014 edition), NOS Hydrographic Surveys Specifications and Deliverables (April 2018 edition), and all Hydrographic Technical Directives issued through the dates of data acquisition. All departures from these standard practices are described in this Data Acquisition and Processing Report and/or the relevant Descriptive Reports.

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

Approver Name	Approver Title	Date	Signature
Benjamin K. Evans, CDR, NOAA	Commanding Officer NOAA Ship Rainier	01/30/2019	Digitally signed by EVANS.BENJAMIN.K.1237217094 Date: 2019.01.30 09:25:10 -08'00'
James B. Jacobson	Chief Survey Technician NOAA Ship Rainier	01/30/2019	JACOBSON.JAMES.BRYAN.1269664017 I am the author of this document 2019.01.30 08:34:09 -08'00'
Andrew Clos, LT/NOAA	Field Operations Officer NOAA Ship Rainier	01/30/2019	

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	RA Wiring Diagram_2018_generic EM2040 launch.pdf
Sound Speed Sensor Calibration	SBE 19 0281.pdf
	SBE 19plus 4039.pdf
	SBE 19plus 4114.pdf
	SBE 19plus 4306.pdf
	SBE 19plus 4343.pdf
	SBE 19plus 4676.pdf
	SBE 19plus 4778.pdf
	SBE 19plus V2 7530.pdf
	2018 SVP 70 Calibration Certificates.pdf
	AML 008565.pdf
Vessel Offset	2801 & 2802 ReportWITHimages.pdf
	NOAA_2803.pdf
	NOAA_2804.pdf
	CFR 83 Ship Survey Report Rev A Survey.pdf
	2018_WaterLine_Loading.pdf
Position and Attitude Sensor Calibration	2018 POS-MV Calibration Report.pdf
	2018 POS-MV Configuration Report.pdf
Echosounder Confidence Check	2018 Reference Surface Comparison.pdf
Echosounder Acceptance Trial Results	RA_Ice_TxRx_2014-final.pdf
	Rainier_Launch_EM2040_Acceptance.pdf