U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey	Hydrographic
Project No.	2016 *Rainier* Field Season
Time frame	April - September

LOCALITY

State(s)	Washington, Alaska
General Locality	Olympic Coast National Marine Sanctuary, Washington North Coast of Kodiak Island, Alaska Resurrection Bay, Alaska

2016

CHIEF OF PARTY

Captain Edward J. Van Den Ameele, NOAA

LIBRARY & ARCHIVES

DATE

Table of Contents

List of Figures

Data Acquisition and Processing Report

NOAA Ship Rainier
Chief of Party: CAPT Edward J. Van Den Ameele, NOAA
Year: 2016
Version: 3.16
Publish Date: 2016-07-08

A Equipment

A.1 Survey Vessels

A.1.1 NOAA Ship Rainier (WTEF)

<table>
<tr><td>Name</td><td colspan="2">NOAA Ship Rainier (WTEF)</td></tr>
<tr><td>Hull Number</td><td colspan="2">S221</td></tr>
<tr><td>Description</td><td colspan="2">Steel hydrographic ship</td></tr>
<tr><td>Utilization</td><td colspan="2">Mid-water multibeam, towed side scanning sonar</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>70.4 meters</td></tr>
<tr><td>Beam</td><td>12.8 meters</td></tr>
<tr><td>Max Draft</td><td>4.7 meters</td></tr>
<tr><td rowspan="3">Most Recent Full Static Survey</td><td>Date</td><td>2014-04-20</td></tr>
<tr><td>Performed By</td><td>The IMTEC Group, Ltd.</td></tr>
<tr><td>Discussion</td><td>During the Rainier's 2014 dry-dock period, in conjunction with the installation of the new ice hardened transducers for the Kongsberg EM 710 multibeam system, the IMTEC Group, Ltd. was contracted to conduct a sensor alignment and orthogonal coordinate survey report. The spatial relationship between the ship’s granite block, IMU, transducer array, POS/MV antennae, and multiple ship reference points were all determined.</td></tr>
</table>

Most Recent Partial Static Survey	*Date*	2015-04-20
	Performed By	NOAA Ship Rainier personel
	Discussion	In preparation for SSS towing, ship's personnel measured the position of the S221 towpoint associated with the A-frame installed in spring of 2015. Measurements were made relative to two existing benchmarks located on the ship's port and starboard rails on the fantail. Using the known position of these benchmarks enabled the establishment of the position of the towpoint in relation to ship's reference point. Values measured and derived may be found in the "SSS_Offsets" report attached to this document. The relative position of the towpoint was then used to generate corresponding HVF.
Most Recent Full Offset Verification	Full offset verification was not performed.	
Most Recent Partial Offset Verification	*Date*	2016-04-19
	Method Used	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	Discussion	During the 2015-16 winter repair Rainier updated her POS/MV antennas when the PCS was upgraded from a version 4 to a version 5. Using the original tower structure and mounting brackets, the position of the new antennas were verified using a pre-existing benchmark surveyed during the 2014 installation of the EM710 ice hardened transducer. Values measured and derived may be found in the "S221_POS_GPS_Ant.pdf" report attached to this document.

Most Recent Static Draft Determination	*Date*	2014-04-20
	Method Used	Survey personnel record direct measurements to waterline from port and starboard benchmarks.
	Discussion	During her 2014 dry-dock in Lake Union, Rainier had a new ice hardened transducer installed for her multibeam sonar system. As part of this installation, The IMTEC Group, Ltd. performed a survey of the entire sonar system in relation to the ship's granite block and several benchmarks located about the ship. This survey included two benchmarks positioned to facilitate waterline measurements. These two benchmarks are located on the gunwale lip, both port and starboard, close to in-line with the IMU. Prior to any multibeam data collection with the ship, an Impulse 200 LR laser rangefinder is held level to the gunwale lip directly on the benchmark and distance shots are taken directly to the surface of the water. Six measurements are taken from each benchmark. Both the port and starboard measurements are individually averaged together to derive a final value. A new waterline measurement is acquired prior to every day of survey operation and when a significant change to the draft occurs (ex; dropping the launches). See section C.2.1 of this report for information regarding the use of waterline measurements in data processing.

Most Recent Dynamic Draft Determination	*Date*	2014-07-24
	Method Used	The ellipsoidally referenced method
	Discussion	The Post-Processed Kinematic (PPK) GPS methodology as outlined in the FPM (1.4.2.1.2.1—Dynamic Draft Measurement Techniques) was used to determine the settlement and squat values of Rainier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by Rainier.

Figure 1: NOAA Ship Rainier (S221)

A.1.2 RA3 (WZ2573)

Name	RA3 (WZ2573)
Hull Number	2803

<table>
<tr><td>Description</td><td colspan="2">Aluminum hull Jensen survey launch</td></tr>
<tr><td>Utilization</td><td colspan="2">Shallow water multibeam, hull mounted side scanning sonar</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="3">Most Recent Full Static Survey</td><td>Date</td><td>2009-03-01</td></tr>
<tr><td>Performed By</td><td>National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch</td></tr>
<tr><td>Discussion</td><td>During the 2008-2009 winter repair period a brand new Jensen (2803) launch was constructed and delivered to Rainier. Personnel from the National Geodetic Survey's Geodetic Services Division determined the spatial relationship of various sensors and reference points in relation to the POS/MV IMU. In all, seven benchmarks in strategic places around the hull, two GPS antennae, and the IMU were positioned.</td></tr>
<tr><td>Most Recent Partial Static Survey</td><td colspan="2">Partial static survey was not performed.</td></tr>
<tr><td>Most Recent Full Offset Verification</td><td colspan="2">Full offset verification was not performed.</td></tr>
</table>

Most Recent Partial Offset Verification	*Date*	2016-05-18
	Method Used	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	Discussion	During the 2014-15 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2015 Sonar offset measurements” and “2016 Sonar Offsets.pdf” reports attached to this document. During the 2015-16 winter repair period additional checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. Again a counter pitch/roll matrix corrected the measured offsets by applying roll and pitch values measured using the POS/MV. Values measured and derived may be found in the “2016 Launch GPS Offsets” report attached to this document.

Most Recent Static Draft Determination	*Date*	2016-04-18
	Method Used	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	Discussion	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 “2016 Waterline measurements” and “WaterLine_Loading_2016” reports attached to this document.

Most Recent Dynamic Draft Determination	*Date*	2015-03-09
	Method Used	Dynamic draft deternined using historical values.
	Discussion	Launches found aboard the NOAA Ship Fairweather, Rainier, and soon Thomas Jefferson are all of the same class with effectively the same hull design and characteristics. 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 Rainier Jensen launches use this single dynamic draft table for 2016 field season. See the report "FA_classHSL_DynamicDraft" attached to this document for more information.

Figure 2: Rainier survey launch RA3 (2803)

A.1.3 RA4 (WZ2574)

<table>
<tr><td>Name</td><td>RA4 (WZ2574)</td></tr>
<tr><td>Hull Number</td><td>2801</td></tr>
<tr><td>Description</td><td>Aluminum hull Jensen survey launch</td></tr>
<tr><td>Utilization</td><td>Shallow water multibeam, hull mounted side scanning sonar</td></tr>
<tr><td>Dimensions</td><td><table><tr><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></table></td></tr>
<tr><td>Most Recent Full Static Survey</td><td><table><tr><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>Discussion</td><td>During the 2007-2008 winter repair period, a brand new Jensen (2801) launch was constructed and delivered to Rainier. Personnel from the National Geodetic Survey’s Geodetic Services Division determined the spatial relationship of various sensors and reference points in relation to the POS/MV IMU. Two of the eleven benchmarks located by NGS personnel are positioned on the sonar mounting bracket which was built to precise dimensional standards. These two benchmarks and blueprints of the mounting bracket allowed for the determination of the exact orientation of the Reson 7125 sonar projectors once they were mounted.</td></tr></table></td></tr>
<tr><td>Most Recent Partial Static Survey</td><td>Partial static survey was not performed.</td></tr>
<tr><td>Most Recent Full Offset Verification</td><td>Full offset verification was not performed.</td></tr>
</table>

Most Recent Partial Offset Verification	*Date*	2016-04-18
	Method Used	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	Discussion	During the 2014-15 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. An addition check was performed in 2016, "2016_2801_Sonar offset measurements", that verified the previous results. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/ roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2015 Sonar offset measurements” and “2016 Sonar Offsets.pdf” reports attached to this document. During the 2015-16 winter repair period additional checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. Again a counter pitch/roll matrix corrected the measured offsets by applying roll and pitch values measured using the POS/MV. Values measured and derived may be found in the “2016 Launch GPS Offsets” report attached to this document.

Most Recent Static Draft Determination	*Date*	2016-04-21
	Method Used	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	Discussion	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 “2016 Waterline measurements” and “WaterLine_Loading_2016” reports attached to this document.

Most Recent Dynamic Draft Determination	*Date*	2015-03-09
	Method Used	Dynamic draft deternined using historical values.
	Discussion	Launches found aboard the NOAA Ship Fairweather, Rainier, and soon Thomas Jefferson are all of the same class with effectively the same hull design and characteristics. 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 Rainier Jensen launches use this single dynamic draft table for 2016 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

Figure 3: Rainier survey launch RA4 (2801)

A.1.4 RA5 (WZ2575)

Name	RA5 (WZ2575)

Hull Number	2802	
Description	Aluminum hull Jensen survey launch	
Utilization	Shallow water multibeam, hull mounted side scanning sonar	
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
	Discussion	During the 2007-2008 winter repair period, a brand new Jensen (2802) launch was constructed and delivered to Rainier. Personnel from the National Geodetic Survey's Geodetic Services Division determined the spatial relationship of various sensors and reference points in relation to the POS/MV IMU. Two of the eleven benchmarks located by NGS personnel are positioned on the sonar mounting bracket which was built to precise dimensional standards. These two benchmarks and blueprints of the mounting bracket allowed for the determination of the exact orientation of the Reson 7125 sonar projectors once they were mounted.
Most Recent Partial Static Survey	Partial static survey was not performed.	
Most Recent Full Offset Verification	Full offset verification was not performed.	

Most Recent Partial Offset Verification	*Date*	2016-05-18
	Method Used	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	Discussion	During the 2014-15 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2015 Sonar offset measurements” and “2016 Sonar Offsets.pdf” reports attached to this document. During the 2015-16 winter repair period additional checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. Again a counter pitch/roll matrix corrected the measured offsets by applying roll and pitch values measured using the POS/MV. Values measured and derived may be found in the “2016 Launch GPS Offsets” report attached to this document.

Most Recent Static Draft Determination	*Date*	2016-04-18
	Method Used	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	Discussion	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 “2016 Waterline measurements” and “WaterLine_Loading_2016” reports attached to this document.

Most Recent Dynamic Draft Determination	*Date*	2015-03-09
	Method Used	Dynamic draft deternined using historical values.
	Discussion	Launches found aboard the NOAA Ship Fairweather, Rainier, and soon Thomas Jefferson are all of the same class with effectively the same hull design and characteristics. 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 Rainier Jensen launches use this single dynamic draft table for 2016 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

Figure 4: Rainier survey launch RA5 (2802)

A.1.5 RA6 (WZ2576)

Name	RA6 (WZ2576)	
Hull Number	2804	
Description	Aluminum hull Jensen survey launch	
Utilization	Shallow water multibeam, hull mounted side scanning sonar	
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
	Discussion	During the 2008-2009 winter repair period a brand new Jensen (2804) launch was constructed and delivered to Rainier. Personnel from the National Geodetic Survey's Geodetic Services Division determined the spatial relationship of various sensors and reference points in relation to the POS/MV IMU. In all, seven benchmarks in strategic places around the hull, two GPS antennae, and the IMU were positioned.
Most Recent Partial Static Survey	Partial static survey was not performed.	
Most Recent Full Offset Verification	Full offset verification was not performed.	

Most Recent Partial Offset Verification	*Date*	2016-04-25
	Method Used	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	Discussion	During the 2014-15 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2015 Sonar offset measurements” and “2016 Sonar Offsets.pdf” reports attached to this document. During the 2015-16 winter repair period additional checks were performed to verify the POS/MV antenna coordinates relative to the NGS surveyed cabin BM. Again a counter pitch/roll matrix corrected the measured offsets by applying roll and pitch values measured using the POS/MV. Values measured and derived may be found in the “2016 Launch GPS Offsets” report attached to this document.

Most Recent Static Draft Determination	*Date*	2016-04-18
	Method Used	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	Discussion	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 “2016 Waterline measurements” and “WaterLine_Loading_2016” reports attached to this document.

Most Recent Dynamic Draft Determination	*Date*	2015-03-09
	Method Used	Dynamic draft deternined using historical values.
	Discussion	Launches found aboard the NOAA Ship Fairweather, Rainier, and soon Thomas Jefferson are all of the same class with effectively the same hull design and characteristics. 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 Rainier Jensen launches use this single dynamic draft table for 2016 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

Figure 5: Rainier survey launch RA6 (2804)

A.1.6 RA7

<table>
<tr><td>Name</td><td colspan="2">RA7</td></tr>
<tr><td>Hull Number</td><td colspan="2">1906</td></tr>
<tr><td>Description</td><td colspan="2">Aluminum hull SAFE boat survey skiff</td></tr>
<tr><td>Utilization</td><td colspan="2">Shoreline verification</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>5.8 meters</td></tr>
<tr><td>Beam</td><td>2.6 meters</td></tr>
<tr><td>Max Draft</td><td>0.33 meters</td></tr>
<tr><td>Most Recent Full Static Survey</td><td colspan="2">Full static survey was not performed.</td></tr>
<tr><td>Most Recent Partial Static Survey</td><td colspan="2">Partial static survey was not performed.</td></tr>
<tr><td>Most Recent Full Offset Verification</td><td colspan="2">Full offset verification was not performed.</td></tr>
<tr><td>Most Recent Partial Offset Verification</td><td colspan="2">Partial offset verification was not performed.</td></tr>
<tr><td>Most Recent Static Draft Determination</td><td colspan="2">Static draft determination was not performed.</td></tr>
<tr><td>Most Recent Dynamic Draft Determination</td><td colspan="2">Dynamic draft determination was not performed.</td></tr>
</table>

Figure 6: Rainier survey skiff RA7 (1906)

A.1.7 RA8

Name	RA8	
Hull Number	1905	
Description	Aluminum hull SeaArk survey skiff	
Utilization	Shoreline verification	
Dimensions	*LOA*	5.7 meters
	Beam	2.8 meters
	Max Draft	0.35 meters
Most Recent Full Static Survey	Full static survey was not performed.	
Most Recent Partial Static Survey	Partial static survey was not performed.	
Most Recent Full Offset Verification	Full offset verification was not performed.	
Most Recent Partial Offset Verification	Partial offset verification was not performed.	
Most Recent Static Draft Determination	Static draft determination was not performed.	
Most Recent Dynamic Draft Determination	Dynamic draft determination was not performed.	

Figure 7: Rainier survey skiff RA8 (1905)

A.2 Echo Sounding Equipment

A.2.1 Side Scan Sonars

A.2.1.1 Edgetech Model 4200 (300/600kHz)

Manufacturer	Edgetech
Model	Model 4200 (300/600kHz)
Description	The EdgeTech 4200 system is comprised of a topside system and a stainless steel towfish. All towfish in use by Rainier are dual frequency 300/600kHz capable of simultaneous acquisition in both frequencies. Rainier launches fitted with sidescan (2802 & 2804) were

set up in a hull-mounted configuration. Rainier was set up in a fish-towed configuration using a LCI 9i cable counter, a Markey COM-7X compact CTD winch and 9mm armored cable.

The EdgeTech 4200 uses Multi-Pulse (MP) technology, which places two sound pulses in the water rather than one pulse like conventional side scan sonar systems. This allows the 4200 to be towed at speeds of up to 10 knots while still maintaining 100% bottom coverage. In addition, the MP technology provides twice the resolution when operating at normal tow speeds. When operated in simultaneous dual frequency acquisition mode, speed must be lowered since the two sound pulses in the water alternate between 300 and 600kHz. It is general practice on Rainier to operate the EdgeTech system in single frequency mode, with the frequency being determined by water depth and/or environmental effects.

Serial Numbers	*Vessel Installed On*	2803 (RA3) Hull-mounted	2804 (RA6) Hull-mounted	S221 (Rainier) towed	spare
	TPU s/n	50423	50426	50425	n/a
	Towfish s/n	50508	50507	50516	50517

Specifications	*Frequency*	300 kilohertz		600 kilohertz	
	Along Track Resolution	*Resolution*	1.3 meters	*Resolution*	0.45 meters
		Min Range	50 meters	*Min Range*	50 meters
		Max Range	230 meters	*Max Range*	120 meters
	Across Track Resolution	3.0 centimeters		1.5 centimeters	
	Max Range Scale	150 meters		100 meters	

Manufacturer Calibrations	Manufacturer calibration was not performed.

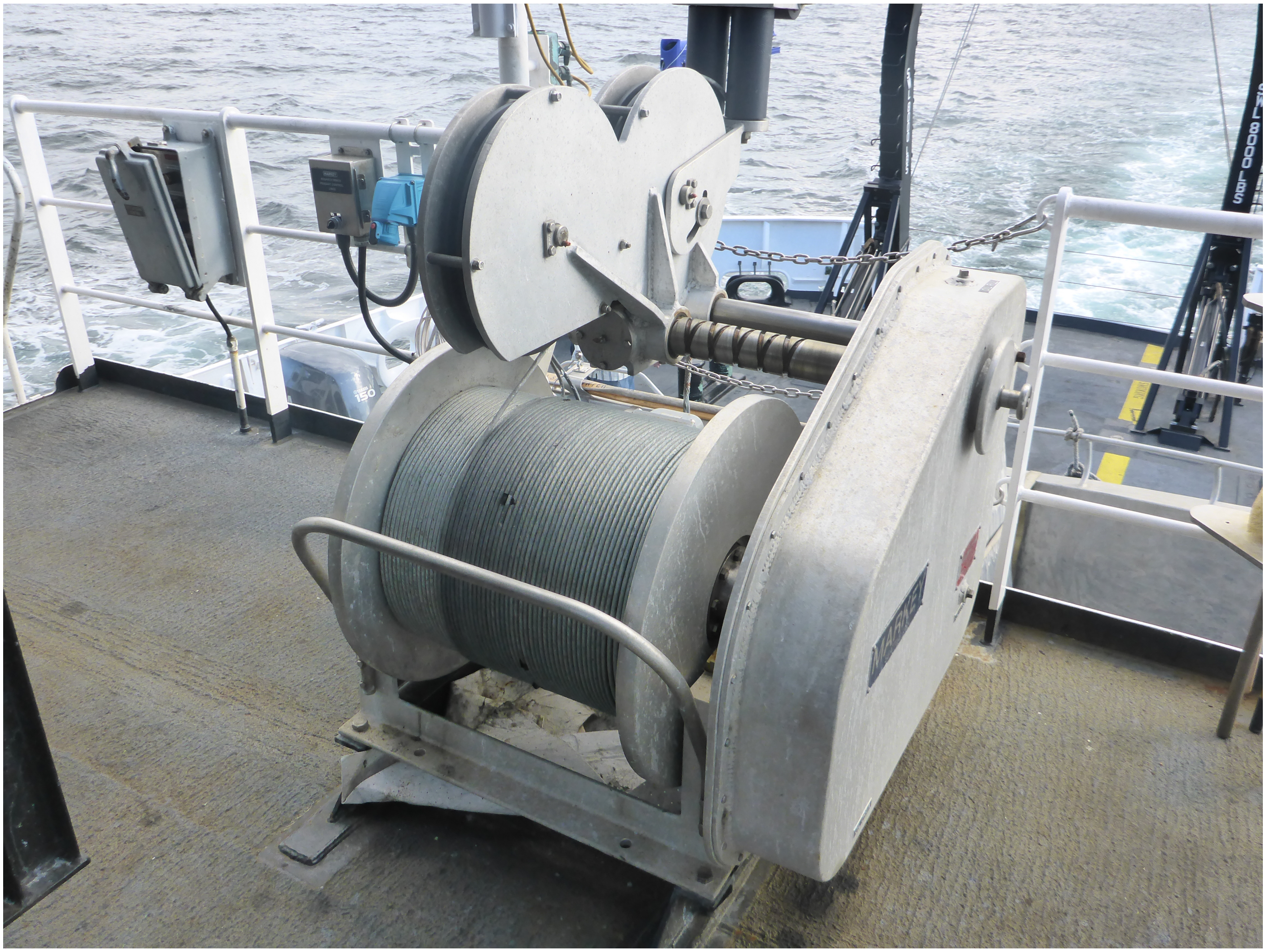

Figure 8: The Markey COM-7X Compact CTD Winch as mounted on the boat deck of Rainier.

Figure 9: The EdgeTech model 4200 (300/600kHz) side scan sonar fish as hull-mounted on 2804 (RA6).

A.2.2 Multibeam Echosounders

A.2.2.1 Kongsberg Model EM710

Manufacturer	Kongsberg
Model	Model EM710
Description	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 m. 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.

Serial Numbers	*Vessel Installed On*		S221
	Processor s/n		0356
	Transceiver s/n		unknown
	Transducer s/n		unknown
	Receiver s/n		218
	Projector 1 s/n		unknown
	Projector 2 s/n		n/a
Specifications	*Frequency*		100 kilohertz
	Beamwidth	*Along Track*	0.5 degrees
		Across Track	1.0 degrees
	Max Ping Rate		25 kilohertz
	Beam Spacing	*Beam Spacing Mode*	Equidistant
		Number of Beams	400
	Max Swath Width		140 degrees
	Depth Resolution		1 centimeters
	Depth Rating	*Manufacturer Specified*	2000 meters
		Ship Usage	400 meters
Manufacturer Calibrations	Manufacturer calibration was not performed.		
System Accuracy Tests	*Vessel Installed On*		S221
	Methods		DESCRIBE REFERENCE SURFACE
	Results		See attached "2016 Reference Surface Comparison" report.
Snippets	Sonar does not have snippets logging capability.		

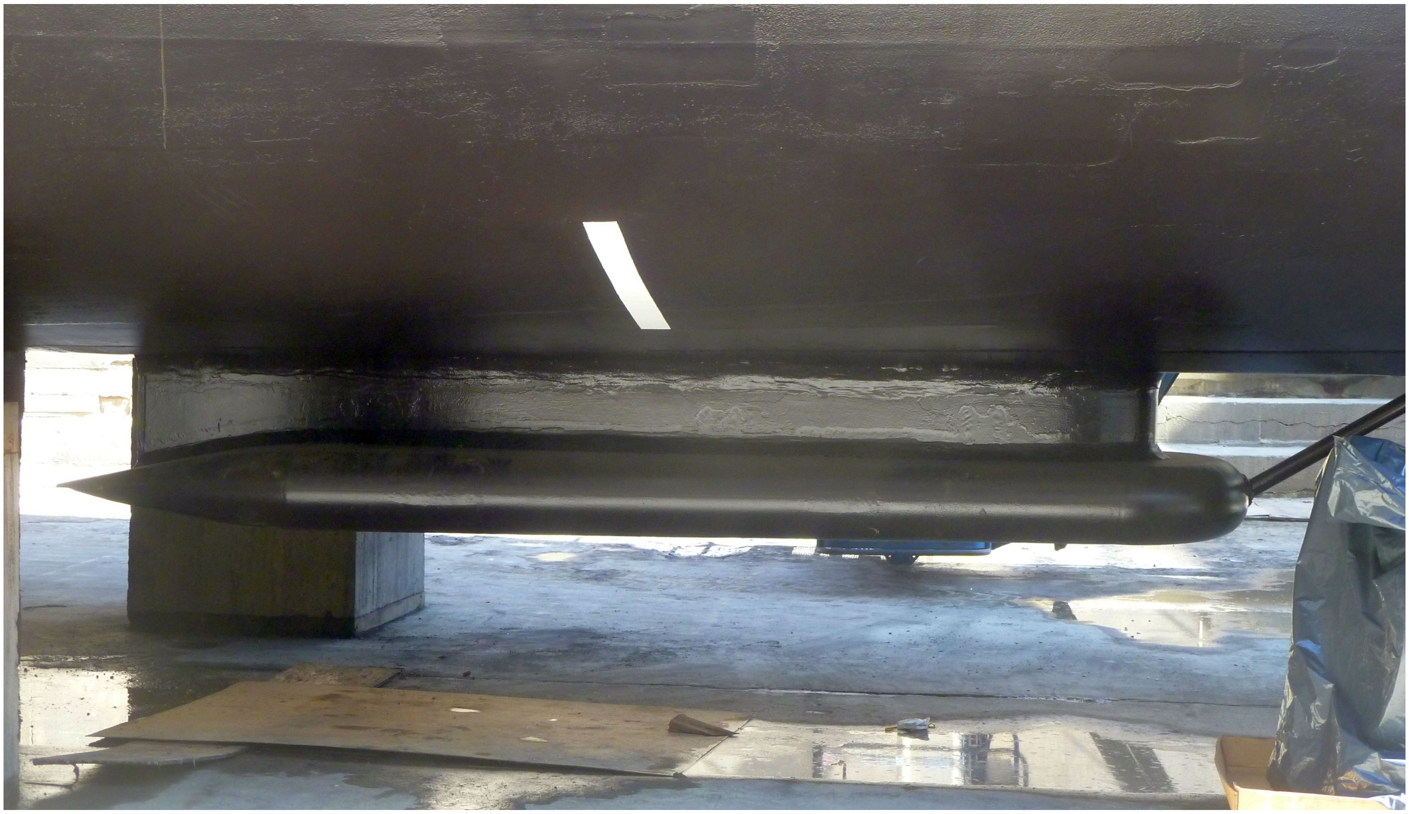

Figure 10: Kongsberg EM710 sonar transducer housing on Rainier (S221).

A.2.2.2 Reson SeaBat 7125-B

Manufacturer	Reson
Model	SeaBat 7125-B
Description	The Reson SeaBat 7125-B is a dual frequency (200/400 kHz), high-resolution multibeam echo sounder system for shallow-water depths. The recommended maximum range at 200kHz is 500m resulting in a 220 m depth limit for full swath coverage on a flat bottom. The 400kHz setting maximum range is 200m resulting in a 87m depth limit for full swath coverage on a flat bottom. The transducer assembly consists of single flat-faced receiver array and two projectors, one for each frequency. These systems included the optional Reson SVP 71 surface sound velocity probe. The SeaBat 7125 measures water depths across a 128° swath in both high and low frequency. Beamforming is conducted in either equi-angle or equidistant mode. Equidistant mode is useful to produce soundings at a uniform distance apart across the entire swath-width of a ping at the cost of less sounding density near nadir. Equi-angle mode is good for maximum ensonification of the bottom directly under the

<table>
<tr><td></td><td colspan="5">launch at the cost of sparse sounding density in the outer beams. Rainier launches typically acquire data in equidistant mode unless running development lines directly over a feature of interest.

In the 200kHz mode the system has a beamwidth of 1° x 2° and in the 400kHz mode has a beamwidth of 0.5° x 1°. At 200kHz, the SeaBat 7125 generates 256 beams per ping. At 400kHz, the system generates 256 or 512 beams per ping. Typical settings used aboard Rainier are 256 beams, equidistant in low frequency mode and 512 beams, equidistant in high frequency mode.</td></tr>
<tr><td rowspan="7">Serial Numbers</td><td>Vessel Installed On</td><td colspan="2">2801</td><td colspan="2">2803</td></tr>
<tr><td>Processor s/n</td><td colspan="2">2708007</td><td colspan="2">4707073</td></tr>
<tr><td>Transceiver s/n</td><td colspan="2">1515002</td><td colspan="2">1515007</td></tr>
<tr><td>Transducer s/n</td><td colspan="2">n/a</td><td colspan="2">n/a</td></tr>
<tr><td>Receiver s/n</td><td colspan="2">unknown</td><td colspan="2">unknown</td></tr>
<tr><td>Projector 1 s/n</td><td colspan="2">unknown</td><td colspan="2">unknown</td></tr>
<tr><td>Projector 2 s/n</td><td colspan="2">unknown</td><td colspan="2">unknown</td></tr>
<tr><td rowspan="11">Specifications</td><td>Frequency</td><td colspan="2">200 kilohertz</td><td colspan="2">400 kilohertz</td></tr>
<tr><td rowspan="2">Beamwidth</td><td>Along Track</td><td>2.0 degrees</td><td>Along Track</td><td>1.0 degrees</td></tr>
<tr><td>Across Track</td><td>1.0 degrees</td><td>Across Track</td><td>0.5 degrees</td></tr>
<tr><td>Max Ping Rate</td><td colspan="2">50 hertz</td><td colspan="2">50 hertz</td></tr>
<tr><td rowspan="2">Beam Spacing</td><td>Beam Spacing Mode</td><td>Equidistant</td><td>Beam Spacing Mode</td><td>Equidistant</td></tr>
<tr><td>Number of Beams</td><td>256</td><td>Number of Beams</td><td>512</td></tr>
<tr><td>Max Swath Width</td><td colspan="2">128 degrees</td><td colspan="2">128 degrees</td></tr>
<tr><td>Depth Resolution</td><td colspan="2">5 millimeters</td><td colspan="2">5 millimeters</td></tr>
<tr><td rowspan="2">Depth Rating</td><td>Manufacturer Specified</td><td>500 meters</td><td>Manufacturer Specified</td><td>200 meters</td></tr>
<tr><td>Ship Usage</td><td>200 meters</td><td>Ship Usage</td><td>50 meters</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Manufacturer Calibrations</td><td colspan="5">Manufacturer calibration was not performed.</td></tr>
</table>

System Accuracy Tests	*Vessel Installed On*	2801 and 2803
	Methods	The reference surface used for launch-to-launch sonar system comparisons is located near Shilshole Marina, Washington and consists of a set of 7 parallel lines and a single crossline. The reference surface slopes up to the southeast from a depth of 100 feet to a depth of 40 feet. Lines are spaced to provide for a generous overlap of soundings. Data for reference surfaces was collected using the 7125 systems in both high (400 kHz) and low (200 kHz) frequency in equi-angle mode for 2801 and 2803. Only high (400 kHz) frequency lines in equi-angle mode were collected by 2802 and 2804. CUBE Reference surfaces with a 1-meter resolution were created for each system and frequency. All surfaces were referenced to MLLW. Because Rainier did not have the true value for the Shilshole reference surface on hand, the 2801 Reson 7125 high frequency reference surface was considered as the “zero” datum for all comparisons.
	Results	See attached "2016 Reference Surface Comparison" report.
Snippets	Sonar has snippets logging capability.	

Figure 11: Reson SeaBat 7125-B mounted on survey launch 2801.

A.2.2.3 Reson Model SeaBat 7125 SV2

<table>
<tr><td>Manufacturer</td><td>Reson</td></tr>
<tr><td>Model</td><td>Model SeaBat 7125 SV2</td></tr>
<tr><td>Description</td><td>The Reson SeaBat 7125 SV2 is a dual frequency (200/400 kHz), high-resolution multibeam echo sounder system for shallow-water depths. The primary difference between this system and the earlier SeaBat 7125-B is the TC 2181 dual-frequency projector unit that operates at either 400 or 200kHz. This single projector replaces two separate projectors (200 & 400 kHz) used in the SeaBat 7125-B. In addition, the functions of the Link Control Unit (LCU) have been entirely replaced by upgrades to the projector /receiver units and therefore the LCU bottle is no longer present in the SeaBat 7125 SV2.

The recommended maximum range at 200kHz is 500m resulting in a 220 m depth limit for full swath coverage on a flat bottom. The 400kHz setting maximum range is 200m resulting in a 87m depth limit for full swath coverage on a flat bottom. The transducer assembly consists of single flat-faced receiver array and the TC 2181 projector mounted in a “T” configuration with the receiver perpendicular to the direction of travel. This system also includes the optional Reson SVP 71 surface sound velocity probe.

The SeaBat 7125 SV2 measures water depths across a 128° swath in both high and low frequency. Beamforming is conducted in either equi-angle or equidistant mode. Equidistant mode is useful to produce soundings at a uniform distance apart across the entire swath-width of a ping at the cost of less sounding density near nadir. Equi-angle mode is good for maximum ensonification of the bottom directly under the launch at the cost of sparse sounding density in the outer beams. Rainier launches typically acquire data in equidistant mode unless running development lines directly over a feature of interest.

In the 200kHz mode the system has a beamwidth of 1° x 2° and in the 400kHz mode has a beamwidth of 0.5° x 1°. At 200kHz, the SeaBat 7125 generates 256 beams per ping. At 400kHz, the system generates 256 or 512 beams per ping. Typical settings used aboard Rainier are 256 beams, equidistant in low frequency mode and 512 beams, equidistant in high frequency mode.</td></tr>
<tr><td>Serial Numbers</td><td><table>
<tr><td>Vessel Installed On</td><td>2802</td><td>2804</td></tr>
<tr><td>Processor s/n</td><td>18343513086</td><td>18343413083</td></tr>
<tr><td>Transceiver s/n</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Transducer s/n</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Receiver s/n</td><td>unknown</td><td>unknown</td></tr>
<tr><td>Projector 1 s/n</td><td>unknown</td><td>unknown</td></tr>
<tr><td>Projector 2 s/n</td><td>None</td><td>None</td></tr>
</table></td></tr>
</table>

<table>
<tr><td rowspan="11">Specifications</td><td>Frequency</td><td colspan="2">200 kilohertz</td><td colspan="2">400 kilohertz</td></tr>
<tr><td rowspan="2">Beamwidth</td><td>Along Track</td><td>2.0 degrees</td><td>Along Track</td><td>1.0 degrees</td></tr>
<tr><td>Across Track</td><td>1.0 degrees</td><td>Across Track</td><td>0.5 degrees</td></tr>
<tr><td>Max Ping Rate</td><td colspan="2">50 hertz</td><td colspan="2">50 hertz</td></tr>
<tr><td rowspan="2">Beam Spacing</td><td>Beam Spacing Mode</td><td>Equidistant</td><td>Beam Spacing Mode</td><td>Equidistant</td></tr>
<tr><td>Number of Beams</td><td>256</td><td>Number of Beams</td><td>512</td></tr>
<tr><td>Max Swath Width</td><td colspan="2">140 degrees</td><td colspan="2">140 degrees</td></tr>
<tr><td>Depth Resolution</td><td colspan="2">6 millimeters</td><td colspan="2">6 millimeters</td></tr>
<tr><td rowspan="2">Depth Rating</td><td>Manufacturer Specified</td><td>450 meters</td><td>Manufacturer Specified</td><td>175 meters</td></tr>
<tr><td>Ship Usage</td><td>200 kilometers</td><td>Ship Usage</td><td>50 meters</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Manufacturer Calibrations</td><td colspan="5">Manufacturer calibration was not performed.</td></tr>
<tr><td rowspan="3">System Accuracy Tests</td><td>Vessel Installed On</td><td colspan="4">2802 and 2804</td></tr>
<tr><td>Methods</td><td colspan="4">The reference surface used for launch-to-launch sonar system comparisons is located near Shilshole Marina, Washington and consists of a set of 7 parallel lines and a single crossline. The reference surface slopes up to the southeast from a depth of 100 feet to a depth of 40 feet. Lines are spaced to provide for a generous overlap of soundings. Data for reference surfaces was collected using the 7125 systems in both high (400 kHz) and low (200 kHz) frequency in equi-angle mode for 2801 and 2803. Only high (400 kHz) frequency lines in equi-angle mode were collected by 2802 and 2804. CUBE Reference surfaces with a 1-meter resolution were created for each system and frequency. All surfaces were referenced to MLLW. Because Rainier did not have the true value for the Shilshole reference surface on hand, the 2801 Reson 7125 high frequency reference surface was considered as the “zero” datum for all comparisons.</td></tr>
<tr><td>Results</td><td colspan="4">See attached "2016 Reference Surface Comparison" report.</td></tr>
<tr><td>Snippets</td><td colspan="5">Sonar has snippets logging capability.</td></tr>
</table>

Figure 12: Reson SeaBat 7125 SV2 mounted on survey launch 2804.

A.2.3 Single Beam Echosounders

A.2.3.1 Odom Hydrographic Systems, Inc. Echotrac CV200

Manufacturer	Odom Hydrographic Systems, Inc.
Model	Echotrac CV200
Description	The Odom Echotrac CV200 is a rack mounted dual frequency single beam echo sounder. As a frequency agile unit, it is capable of producing high band frequencies between 100kHz- 1MHz and low band frequencies between 3.5kHz-50kHz. A dual frequency Odom transducer (200 kHz, 24 kHz) was selected to be paired with the Echotrac CV200. The beam widths for the high and low frequency are 4° (conical) and 20° (conical) respectively. Soundings are acquired in meters for both frequencies and saved digitally for future review.

Serial Numbers	*Vessel*	2701			
	Processor s/n	0041525			
	Transducer s/n	unknown			
Specifications	*Frequency*	24 kilohertz		200 kilohertz	
	Beamwidth	*Along Track*	20 degrees	*Along Track*	4 degrees
		Across Track	20 degrees	*Across Track*	4 degrees
	Max Ping Rate	20 hertz		20 hertz	
	Depth Resolution	1 centimeters		1 centimeters	
	Depth Rating	*Manufacturer Specified*	1000 meters	*Manufacturer Specified*	200 meters
		Ship Usage	50 meters	*Ship Usage*	50 meters
Manufacturer Calibrations	Manufacturer calibration was not performed.				
System Accuracy Tests	System accuracy test was not performed.				

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 Positioning and Attitude Equipment

A.4.1 Applanix POS/MV

Manufacturer	Applanix
Model	POS MV V5
Description	New for the 2016 field season, Rainier and all of her launches were upgraded from the Applanix POS/MV 320 version 4 to the 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.

PCS

Manufacturer	Applanix
Model	POS/MV 320 V5
Description	The POS Computer System (PCS) consists of two Global Navigation Satellite System (GNSS) receiver cards in a 19-inch Rack Mounted chassis. The primary receiver card provides the position, velocity and raw observation information. It also provides a one Pulse Per Second (PPS) strobe and time message that the POS MV uses to accurately time-stamp data output with Universal Time Coordinated (UTC). The secondary receiver card, in conjunction with the primary receiver card, allows the POS MV to compute GNSS heading aiding by performing carrier phase differential measurements between the two GNSS receivers. The PCS also contains the electronics necessary for the GNSS Azimuth Measurement Subsystem (GAMS). This feature allows the system to use GNSS data blended with the inertial navigation solution to achieve exceptional accuracy in the measurement of heading.
Firmware Version	8.63
Software Version	8.60
Serial Numbers	see below

Serial Numbers

Vessel Installed On	S221	2801 (RA4)	2802 (RA5)	2803 (RA3)	2804 (RA6)
PCS s/n	7273	7264	7162	7272	7274

IMU

Manufacturer	Applanix
Model	LN200
Description	The LN200 Inertial Measurement Unit (IMU) consists of three solid-state linear accelerometers and three solid-state gyros arranged in a triaxial orthogonal array. The analog output of these accelerometers and gyros is converted to digital in the IMU prior to output to the POS Computer System (PCS). Only after the PCS receives these measurements from the IMU are the measurements of motion calculated.
Serial Numbers	see below
Certification	IMU certification report was not produced.

Serial Numbers

Vessel Installed On	S221	2801 (RA4)	2802 (RA5)	2803 (RA3)	2804 (RA6)
IMU s/n	353	693	7162	334	355

Antennas

Manufacturer	Trimble
Model	Aeo Antenna Technology Inc (re-branded as Trimble)
Description	Used by S221

Serial Numbers	*Vessel Installed On* / *Antenna s/n* / *Port or Starboard* / *Primary or Secondary*: S221, 8197, Port, Primary; S221, 8188, Starboard, Secondary

Vessel Installed On	*Antenna s/n*	*Port or Starboard*	*Primary or Secondary*
S221	8197	Port	Primary
S221	8188	Starboard	Secondary

Manufacturer	Trimble
Model	Aeo Antenna Technology Inc (re-branded as Trimble)
Description	Used by 2801 & 2802

Serial Numbers

Vessel Installed On	*Antenna s/n*	*Port or Starboard*	*Primary or Secondary*
2801	8196	Port	Primary
2801	8186	Starboard	Secondary
2802	8184	Port	Primary
2802	8182	Starboard	Secondary

Manufacturer	Trimble
Model	Aeo Antenna Technology Inc (re-branded as Trimble) AT1675-540TS
Description	Used by 2803 & 2804

Serial Numbers

Vessel Installed On	*Antenna s/n*	*Port or Starboard*	*Primary or Secondary*
2803	8187	Port	Primary
2803	8181	Starboard	Secondary
2804	8978	Port	Primary
2804	8979	Starboard	Secondary

GAMS Calibration

Vessel	2801	2802	2803	2804	S221
Calibration Date	2016-05-24	2016-05-20	2016-05-26	2016-05-18	2016-06-21

Configuration Reports

Vessel	2801	2802	2803	2804	S221
Report Date	2016-05-24	2016-05-20	2016-05-26	2016-05-18	2016-06-21

A.4.2 DGPS

Description	All Rainier launches are equipped with beacon receivers. These receivers are tuned to the closest available US Coast Guard maintained beacon transmitter with a reliable signal. The USCG beacon selected may change throughout the survey day depending

<table>
<tr><td></td><td>on the received signal strength and position of the survey platform. GPS correctors are fed to the Applanix POS/MVs to produce real time differentially corrected positions.</td></tr>
<tr><td>Antennas</td><td>
<table>
<tr><td>Manufacturer</td><td>Furuno Electric Co. Ltd.</td></tr>
<tr><td>Model</td><td>GR-8 antenna coupler with preamp, FAW-1.2 whip antenna</td></tr>
<tr><td>Description</td><td>This unit consists of a preamp unit with a screw-in 1.2 meter whip antenna.</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>2801 (RA4)</td><td>2802 (RA5)</td><td>2804 (RA6)</td></tr>
<tr><td>Antenna s/n</td><td>1-0785</td><td>1-1486</td><td>1-1499</td></tr>
</table>
</td></tr>
</table>
<table>
<tr><td>Manufacturer</td><td>Trimble</td></tr>
<tr><td>Model</td><td>DSM212L</td></tr>
<tr><td>Description</td><td>The Trimble DMS212L is a combined L1 GPS and MSK H-field loop antenna.</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>2803 (RA3)</td></tr>
<tr><td>Antenna s/n</td><td>unknown</td></tr>
</table>
</td></tr>
</table>
</td></tr>
<tr><td>Receivers</td><td>
<table>
<tr><td>Manufacturer</td><td>Furuno</td></tr>
<tr><td>Model</td><td>GR-80</td></tr>
<tr><td>Description</td><td>The Furuno GR-80 DGPS Beacon Receiver acquires differential error correction messages (RTCM SC104 format) broadcast by US Coast Guard radio beacons operating in the 283.5 to 325 kHz frequency range. The differential error correction messages are output via a serial port in NMEA 0183 protocol for use with an associated GPS receiver This results in differentially corrected position data with better than 2 meter accuracy.</td></tr>
<tr><td>Firmware Version</td><td>unknown</td></tr>
<tr><td>Serial Numbers</td><td>
<table>
<tr><td>Vessel Installed On</td><td>2801 (RA4)</td><td>2802 (RA5)</td><td>2803 (RA3)</td><td>2804 (RA6)</td></tr>
<tr><td>Antenna s/n</td><td>3506-6743</td><td>3506-8043</td><td>3506-8385</td><td>3506-8032</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

A.4.3 Trimble Backpacks

Manufacturer	Trimble
Model	Pathfinder Pro XRS

<table>
<tr><td>Description</td><td colspan="2">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. This GPS 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.</td></tr>
<tr><td>Serial Numbers</td><td colspan="2">While the Trimble backpacks themselves have no serial numbers, the individual components they contain do.</td></tr>
<tr><td rowspan="5">Antennas</td><td>Manufacturer</td><td>Trimble</td></tr>
<tr><td>Model</td><td>GPS Pathfinder Pro XRS Antenna (part number 33580-50)</td></tr>
<tr><td>Description</td><td>Integrated L1 GPS/Beacon/Satellite differential antenna</td></tr>
<tr><td rowspan="2">Serial Numbers</td><td>0220309434</td></tr>
<tr><td>0220309470</td></tr>
<tr><td rowspan="6">Receivers</td><td>Manufacturer</td><td>Trimble</td></tr>
<tr><td>Model</td><td>Pathfinder Pro XRS</td></tr>
<tr><td>Description</td><td>GPS receiver with built-in USCG beacon capabilities.</td></tr>
<tr><td>Firmware Version</td><td>unknown</td></tr>
<tr><td rowspan="2">Serial Numbers</td><td>0224070094</td></tr>
<tr><td>0224070154</td></tr>
</table>

Field Computers	*Manufacturer*	Panasonic
	Model	Toughbook CF-30
	Description	The Panasonic Toughbook CF-30 comes standard with a 1.66 GHz Intel Core Duo processor in a sealed all-weather design magnesium alloy case. The screen consists of a 13.3” sunlight-viewable display. Other design elements include a shock-mounted 160GB hard drive, a moisture and dust-resistant LCD, keyboard and touchpad. This laptop also has no cooling fan and instead dissipates heat "evenly" through the chassis. Having no fan ensures a better seal against dust and moisture. All external connection ports are also protected with waterproof flaps and covers.
	Operating System	Windows XP
	Serial Numbers	8HKSB80775 (Field2) 8HKSB80724 (Field 4)
	Manufacturer	Panasonic
	Model	Toughbook CF-31
	Description	The Panasonic Toughbook CF-31 comes standard with a i7-3520M 2.90GHz vPro Intel Core processor in a sealed all-weather design magnesium alloy case. The screen consists of a 13.1” sunlight-viewable display. Other design elements include a shock-mounted 322GB hard drive, a moisture and dust-resistant LCD, keyboard and touchpad. This laptop also has no cooling fan and instead dissipates heat "evenly" through the chassis. Having no fan ensures a better seal against dust and moisture. All external connection ports are also protected with waterproof flaps and covers.
	Operating System	Windows 7 (x64)
	Serial Numbers	3ITSB60204 (Field5) 3ITSB60201 (Field6)
	Manufacturer	Panasonic
	Model	Toughbook CF-54
	Description	The Panasonic Toughbook CF-54 is equipped with a Core i5-5300U 2.3 GHz Intel processor and 16 GB of installed RAM memory and a 1TB shock-mounted hard disk drive. It is MIL-STD-810G compliant and features a spill-resistant, full magnesium alloy case design and a storage drive heater. The screen consists of a 14” sunlight-viewable display. All external connection ports are protected with water resistant flaps and covers.
	Operating System	Windows 7 Professional (32-bit)
	Serial Numbers	5ITSA19236 (Field 1) 5ITSA19168 (Field3)

DQA Tests	*Date*	2016-04-21
	Serial Number	0224070094 & 0224070154
	Methods	During a two day period in April 2016, horizontal control hardware was tested on benchmark S220 2011 at NOAA Pacific Marine Center in Newport Oregon. For each of Rainier's two Trimble backpacks, data were collected over the benchmark for 5 minutes in both differential and non-differential modes. Trimble Base stations, survey cameras capable of recording GPS positions and handheld GPS units were also tested.
	Results	The largest difference seen between the published position of the benchmark and Trimble backpack positions produced during DQA testing was 1.413 meters in differential and 2.22 meters in non-differential.

Figure 13: A Toughbook laptop computer Field5 in use on a skiff collecting shoreline data.

A.4.4 Laser Rangefinders

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.
Serial Numbers	108786
DQA Tests	DQA test was not performed.

Manufacturer	Leica
Model	DISTO lite5
Description	The Leica DISTO lite5 is a splash and dust proof handheld laser rangefinder that emits a Class II 0.95mW laser on a wavelength of 620-690nm. Ranges measurable vary from 0.2m up to 200m with the smallest unit displayed 1mm. Measuring accuracy (at 2x standard deviation) is typically ± 3mm, ± 5mm at the instrument's extreme range.
Serial Numbers	40300556
DQA Tests	DQA test was not performed.

Figure 14: The Leica DISTO lite5 being used to verify antennae separation of a survey launch.

A.4.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

A.5 Sound Speed Equipment

A.5.1 Sound Speed Profiles

A.5.1.1 CTD Profilers

A.5.1.1.1 SEA-BIRD ELECTRONICS, INC. SBE 19 SEACAT

Manufacturer	SEA-BIRD ELECTRONICS, INC.
Model	SBE 19 SEACAT
Description	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.
Serial Numbers	*Vessel Installed On*: n/a *CTD s/n*: 192472 -0281 (green)
Calibrations	*CTD s/n*: 192472-0281 *Date*: 2015-11-28 *Procedures*: The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.

Figure 15: 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.5.1.1.2 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.

Serial Numbers

Vessel Installed On	n/a	n/a	n/a	n/a	n/a
CTD s/n	19P26069-4039 (black)	19P27151-4114 (yellow)	19P30319-4306 (blue)	19P31464-4343 (purple)	19P-7530 (red)

Calibrations

CTD s/n	19P26069-4039	19P27151-4114	19P30319-4306	19P31464-4343	19P-7530
Date	2015-11-20	2015-11-18	2015-11-19	2015-11-17	2015-11-24
Procedures	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.

Figure 16: 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.5.1.2 Sound Speed Profilers

A.5.1.2.1 Rolls-Royce Group ODIM Brooke Ocean MVP200 Moving Vessel Profiler (MVP)

Manufacturer	Rolls-Royce Group ODIM Brooke Ocean
Model	MVP200 Moving Vessel Profiler (MVP)
Description	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. During the Kodiak 4th of July inport, the original conductor cable that had frayed with age and use was replaced with a new 650 meter cable. 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.
Serial Numbers	(see below)

Serial Numbers

Vessel Installed On	S221 Rainier	spare	spare	spare
Sound Speed Profiler s/n	7761	8614	7510	7511

Calibrations	*Sound Speed Profiler s/n*	7761	8614	7510	7511
	Date	2016-04-11	2016-04-11	2016-04-11	2016-04-15
	Procedures	A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.

A.5.1.2.2 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

<table>
<tr><td></td><td>wire contained within the shipboard spool) the profile is completed and the system is ready for another launch.</td></tr>
<tr><td>Serial Numbers</td><td><table><tr><td>Vessel Installed On</td><td>S221 Rainier</td></tr><tr><td>Sound Speed Profiler s/n</td><td>n/a</td></tr></table></td></tr>
<tr><td>Calibrations</td><td>No CTD profiler calibrations were performed.</td></tr>
</table>

Figure 17: Deploying a XBT from the port-side bridge wing of Rainier.

A.5.2 Surface Sound Speed

A.5.2.1 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 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.</td></tr>
<tr><td>Serial Numbers</td><td><table><tr><td>Vessel Installed On</td><td>S221</td><td>S221</td></tr><tr><td>Sound Speed Sensor s/n</td><td>301302</td><td>4408373</td></tr></table></td></tr>
<tr><td>Calibrations</td><td>No CTD profiler calibrations were performed.</td></tr>
</table>

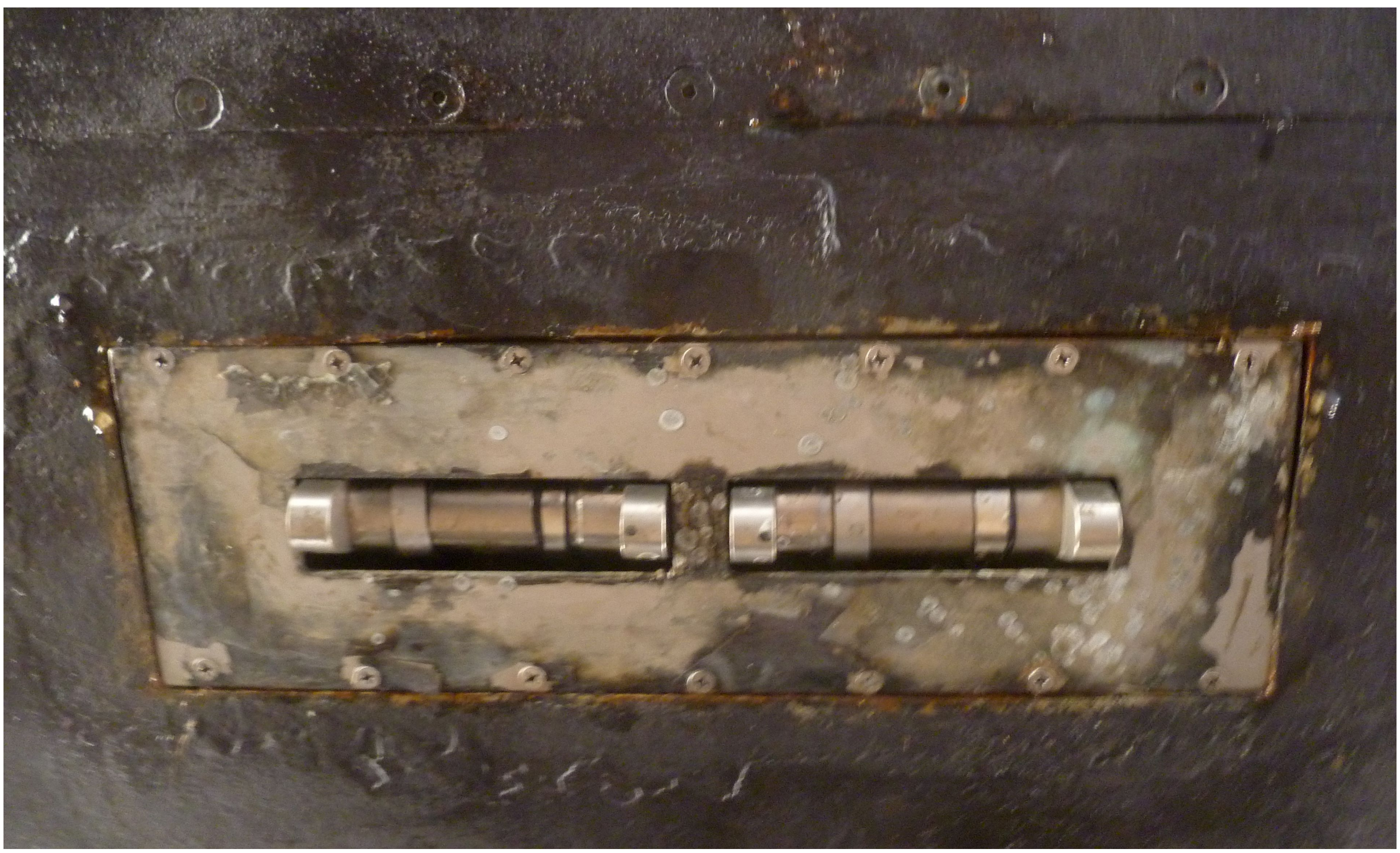

Figure 18: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.

A.5.2.2 Reson Inc. SVP 71

<table>
<tr><td>Manufacturer</td><td>Reson Inc.</td></tr>
<tr><td>Model</td><td>SVP 71</td></tr>
<tr><td>Description</td><td>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.</td></tr>
<tr><td>Serial Numbers</td><td><table><tr><td>Vessel Installed On</td><td>2801</td><td>2802</td><td>2803</td><td>2804</td></tr><tr><td>Sound Speed Sensor s/n</td><td>1511086</td><td>1511089</td><td>1511076</td><td>1511077</td></tr></table></td></tr>
<tr><td>Calibrations</td><td>No CTD profiler calibrations were performed.</td></tr>
</table>

Figure 19: A SVP 71 mounted just aft of a Reson multibeam transducer on a survey launch.

A.6 Horizontal and Vertical Control Equipment

A.6.1 Horizontal Control Equipment

A.6.1.1 Base Station Equipment

Description	In the absence of a local Continuously Operating Reference Station (CORS) network, Rainier maintains at least one GNSS base station during hydrographic operations in the project area. Base station sites are 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 GNSS satellites observed. Base station sites are also selected to be centrally located in the project area to provide maximum coverage. At the recommendation of Applanix, base station sites should fall within 20 kilometers of any POS/MV data collected. Each station consists of either a Trimble NetR5 or Trimble NetR9 GNSS reference receiver interfaced with a Freewave HTP-900RE 900 MHz Ethernet radio all sealed in a watertight Pelican plastic case. A Zephyr Geodetic 2 GNSS antenna is secured atop a Seco fixed-height antenna tripod and connected to the Trimble receiver through a watertight connection fitted in the side of the Pelican case. A UHF antenna on top of an extending pole supported by a standard survey tripod is connected to the Freewave Ethernet radio and provides for remote daily download of the GNSS data. Batteries and solar panels provide power.

GPS Antennas

Manufacturer	Trimble Navigation Ltd.
Model	Zephyr Goedetic 2
Description	The Trimble Zephyr Geodetic 2 antenna is an ideal design for horizontal control work. This antenna incorporates a large proprietary ground plane to “burn up” multipath energy. The Zephyr Geodetic 2 antenna is extremely rugged with a low profile design constructed of weather resistant materials. This antenna is compatible with GNSS signals, including GPS L2C and L5, GLONASS, and even Galileo is supported.
Serial Numbers	30767941 1441031030

GPS Receivers	*Manufacturer*	Trimble Navigation Limited
	Model	NetR5
	Description	The Trimble NetR5 reference station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. With 76 channels it can track all GPS signals (L1/L2/L5) as well as GLONASS (L1/L2). This receiver contains 56 MB of internal storage and has Ethernet ports compatible with HTTP and FTP protocols. Power is provided through a 9.5 V to 28 V DC input on 26 pin D sub connector while an internal 15 hour battery operates as a UPS in the event of power source outage.
	Firmware Version	unknown
	Serial Numbers	4910K61066 (Moe)
	Manufacturer	Trimble Navigation Limited
	Model	NetR9
	Description	The Trimble NetR9 reference station is a multi-channel, multi-frequency GNSS (Global Navigation Satellite System) receiver designed for use as a stand-alone reference station or as part of a GNSS infrastructure solution. With 440 channels is capable of tracking signals from GPS, GLONASS, Galileo, Compass, and QZSS constellations. This receiver contains 8 GB of internal storage and an integrated RJ45 port with full-duplex, auto-negotiate 100Base-T compatible with HTTP and FTP protocols. Power is provided through Power over Ethernet (PoE) or a 9.5 V to 28 V DC input on a Lemo port while an internal 15 hour battery operates as a UPS in the event of power source outage.
	Firmware Version	unknown
	Serial Numbers	5034K69715 (Curly) 5429R49194 (Larry)

UHF Antennas	*Manufacturer*	L-com Global Connectivity
	Model	HGV-906U 800/900 MHz 6 dBi Omnidirectional Antenna
	Description	The HyperGain HGV-906U is a high performance omni directional antenna designed for the 800 MHz / 900 MHz ISM band. It is ideally suited for multipoint, non line of sight and mobile applications where high gain and wide coverage is desired. This antenna's construction features a rugged 1.3" diameter white high intensity fiberglass radome for durability. It is designed for all weather operation.
	Serial Numbers	n/a
	Manufacturer	PCTEL Inc.
	Model	Bluewave BGYD890M
	Description	The BGYD890M Yagi antenna provides directional high gain broadband performance between the frequencies of 890-960 MHz with a 12 dBd gain. Ten 3/8" solid aluminum elements complement the fully welded dipole on the boom. The BGYD890M is protected from the elements with a black powder coat. An integral low loss 2' RG213 feed line with a standard N-female connector provides connectivity. A supplied high strength mounting clamp allows for vertical or horizontal polarization.
	Serial Numbers	n/a

UHF Radios	*Manufacturer*	Freewave
	Model	HTP-900RE
	Description	The FreeWave Technologies HTplus Industrial 900 MHz Radio is an industrial grade high speed Ethernet radio that operates in harsh environments and noisy RF conditions. It features high speed (867 Kbps) over-the-air throughput with strong signal performance, maintaining high sensitivity even in marginal conditions. This radio has a point-to-point range of 15 miles with clear line of sight.
	Firmware Version	n/a
	Serial Numbers	886-3478 Launch RA-5 886-0701 Launch RA-6 886-3434 Launch RA-3 884-8978 Spare 886-0778 Launch RA-4 886-0741 RA Plot Room Rack 885-5935 HORCON Moe 885-8781 Spare 887-0392 HORCON Curly 887-0371 HORCON Larry
Solar Panels	*Manufacturer*	Uni-Solar (United Solar Systems Corp)
	Model	MBC-525
	Description	The Uni-Solar MBC-525 is a flexible 51" X 16" solar panel rated at 22 watts.
	Serial Numbers	n/a

Solar Chargers	*Manufacturer*	Morning Star
	Model	Sun Saver 10 SS-10L-12V
	Description	The Morningstar SunSaver SS-10L-12V is a small solar controller that regulates how much power goes into the storage batteries connected to a solar panel. The amount of power passed to the battery is dependent on the current level of the battery. This power regulation helps to increase long-term battery life. The Sunsaver also includes Low Voltage Disconnect (LVD) which automatically shuts off the load when batteries get to low, also saving on long-term battery life.
	Serial Numbers	n/a
DQA Tests	No DQA tests were performed.	

Figure 20: Base station "Curly" consisting of a Trimble NetR5 receiver interfaced with a Freewave Ethernet radio and associated power control electronics all sealed in a watertight Pelican plastic case.

A.6.1.2 Rover Equipment

No rover equipment was utilized for data acquisition.

A.6.2 Vertical Control Equipment

A.6.2.1 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.6.2.2 Leveling Equipment

Manufacturer	Carl Zeiss
Model	Zeiss Ni2
Description	The Zeiss Ni2 is the first automatic level based on suspended prisms that levels the light path. When set close to level, the internal compensator mechanism (a swinging prism) automatically removes any remaining variation from level. This reduces the need to set the instrument truly level since small inclination deviations are automatically corrected for. The telescope has a magnification power of 32 times and an objective diameter of 40 millimeters. It is 270 millimeters in length and produces an erect image. The cross-hairs form a straight cross with stadia hairs on the vertical hair. In contrast to most other geodetic instruments the cross-hairs only occupy the central 50% of the field of view.
Serial Numbers	87102 67312 100518

Calibrations

Level s/n	87102 and 100518	67312
Date	2015-11-12	2015-12-08
Procedures	The levels were returned to Kuker-Ranken Inc. for annual cleaning, inspection, adjustment, and calibration.	The levels were returned to Kuker-Ranken Inc. for annual cleaning, inspection, adjustment, and calibration. This level required additional work on its compensator.

Kukkamaki

Level s/n	67312, 87102 & 100518
Date	2016-04-18
Procedures	The Kukkamaki procedure used follows that outlined in the User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987.

A.7 Computer Hardware and Software

A.7.1 Computer Hardware

No computer hardware was utilized for data acquisition.

A.7.2 Computer Software

Manufacturer	CARIS
Software Name	HIPS and SIPS (x64)
Version	9.1.0
Service Pack	N/A
Hotfix	N/A
Installation Date	2016-03-21
Use	Processing
Description	CARIS HIPS and SIPS is a comprehensive bathymetric, seafloor imagery and water column data processing software. HIPS & SIPS allows the user to convert raw hydrographic data into a usable format and then compute and apply all correctors. Data may then be visualized and manipulated by the user for analysis and cleaning. Automated data cleaning filters and algorithms assist the user in this process.

Manufacturer	CARIS
Software Name	BASE Editor (x64)
Version	4.1.16
Service Pack	n/a
Hotfix	16
Installation Date	2015-12-10
Use	Processing
Description	CARIS Bathy DataBASE BASE editor allows the user to open all sources of data from historical BASE surfaces, S-57 shoreline files, raster charts to the latest high density multibeam survey in a single space. Once opened, these data can easily be simultaneously examined for consistency. Analysis tools to compare BASE surfaces in their common area ease junction and crossline comparisons. In addition the 3D fly-through offers an easy way to catch data fliers.

Manufacturer	CARIS
Software Name	Notebook
Version	3.1.1
Service Pack	1
Hotfix	2
Installation Date	2016-05-25
Use	Acquisition and Processing
Description	Notebook allows for the quick collection of geo-referenced hydrographic object data and notes in the field. Both NMEA and Trimble formats are supported in CARIS Notebook which allows the user to obtain data directly from a GPS receiver. New S-57 objects can be added and proper S-57 attributes attached during collection.

	Field note descriptions can be attached to new marker objects as attributes. The newly digitized S-57 hydrographic objects can easily be brought directly into ENC production software. Tidal correctors may also be applied to point features attributed with time and height collected in the field.

Manufacturer	Applanix
Software Name	POSPac MMS
Version	7.1.5535.25591
Service Pack	1
Hotfix	n/a
Installation Date	2016-05-25
Use	Processing
Description	The Applanix POSPac Mobile Mapping Suite (MMS) is post-processing software designed to maximize the accuracy potential of the POS/MV (Position and Orientation System – Marine Vessels) system. Highly accurate position and orientation solutions from the GNSS and Inertial data logged to a POS MV system may be obtained despite periods of GNSS outages. Logged POS/MV files are imported into POSPac MMS for automatic analysis and quality checks. When available, data from Rainier installed base stations is also loaded once it receives an OPUS solution. If there is no user installed base stations to reference the acquired POS data to, reference station and precise ephemeris data may be imported from the internet. This produces a SBET (Smoothed Best Estimated Trajectories) file that may be applied in CARIS to produce superior position and attitude data.

Manufacturer	NOAA (HSTP)
Software Name	Pydro
Version	15.13 r5738
Service Pack	n/a
Hotfix	n/a
Installation Date	2016-05-11
Use	Processing
Description	Pydro is a special—purpose hydrographic GIS written by HSTP that provides important functionality for the quality control of NOAA hydrographic survey data. Pydro assists the hydrographer and cartographer in managing feature/object data in the context of other supporting/correlating data ("other" vector data, bathymetry, and raster data)

Manufacturer	HYPACK, Inc.
Software Name	Hypack 2016
Version	16.2.5.0

Service Pack	n/a
Hotfix	n/a
Installation Date	2016-04-19
Use	Acquisition
Description	Hypack and the associated Hysweep software is the primary multibeam and singlebeam data acquisition software used aboard Rainier. Data from sonar, GPS and attitude sensors are logged to the hard drive while real time displays of launch position and sonar coverage are displayed on a digital chart.

Manufacturer	Kongsberg Maritime AS
Software Name	SIS
Version	4.1.4
Service Pack	1
Hotfix	24
Installation Date	2015-01-15
Use	Acquisition
Description	Seafloor Information System (SIS) is produced by Kongsberg Maritime and is supplied as part of the EM710 multi-beam sonar system. This real time software is designed to be the user interface and real time data processing system for the EM710. All necessary sensor interfaces, data displays for quality control and sensor calibration, seabed visualization, data logging, and integrated seabed acoustical imaging capability (sidescan) are standard parts of the software. It operates under the Windows operating system in a rack mounted computer dedicated to control of the EM710.

Manufacturer	Edgetech
Software Name	Discover 4200-MP
Version	35.0.1.204
Service Pack	n/a
Hotfix	n/a
Installation Date	2015-07-16
Use	Acquisition
Description	Discover 4200-MP

Manufacturer	Applanix Corporation
Software Name	MV-POSView
Version	8.46
Service Pack	n/a

Hotfix	n/a
Installation Date	2014-04-14
Use	Acquisition
Description	The MV-POSView controller program is used to configure and operate the POS/MV attitude and positioning system. This program is also used to record the POS/MV .000 files used to produce the SBET files post-applied in CARIS to improve attitude and navigation.

Manufacturer	NOAA (HSTP)
Software Name	Velocipy
Version	15.13 r5839
Service Pack	n/a
Hotfix	n/a
Installation Date	2016-06-17
Use	Acquisition and Processing
Description	Velocipy is a special purpose program written by HSTP to communicate with Sea-Bird sound velocity profiling equipment. With this software, CTD profilers can be initialized and after deployment have the raw conductivity, temperature and pressure data downloaded. These data are then processed into a form usable by CARIS in addition to an archival NODC format.

Manufacturer	ODIM
Software Name	MVP Controller
Version	2.430
Service Pack	n/a
Hotfix	n/a
Installation Date	2015-07-16
Use	Acquisition
Description	MVP Controller

Manufacturer	UNH/CCOM
Software Name	CastTime
Version	2013-031413
Service Pack	n/a
Hotfix	n/a
Installation Date	2014-03-01
Use	Acquisition

Description	CastTime is an application that bridges the gap between sound speed profiling instrumentation and multibeam echosounder acquisition systems. It is designed to assist the hydrographer in deciding when he/she should make a sound speed cast and at what times the casts should be executed. Too few profiles can lead to poor data quality and too many can lead to unnecessary wear and tear on the MVP tow-fish cable and possibly loss of the instrument. CastTime starts with user input seed times for the minimum and maximum allowable times between casts. Using available cast information, surface sound speed, and water depth, CastTime calculates a real time predicted error for the outer beams of the sonar system and recommends a new cast only when the error threshold is surpassed. This allows for the maximum allowable time between casts without adversely affecting data quality.

Manufacturer	UNH/CCOM
Software Name	SVP Editor
Version	1.0.4
Service Pack	n/a
Hotfix	n/a
Installation Date	2014-03-01
Use	Acquisition
Description	SVP Editor is an application that processes MVP data for delivery to Kongsberg Maritime multibeam echosounders for ray bending corrections. The software, which supports import and export of several sensor and software formats, allows for interactive graphical data editing for removal of outliers and/or addition of points for vertical extrapolation. The World Ocean Atlas is used for vertical extrapolation of measured profiles such as the Kongsberg control software demands. Kongsberg Maritime’s acquisition system (Seafloor Information System, or SIS) offers numerous network datagram input/output transmission protocols that allow SVP Editor integration. MVP casts, collected with prompting from CastTime, are processed and extrapolated with by SVP Editor and then transmitted automatically to SIS with little user intervention. SIS treats the incoming sound speed profiles just like any other sensor and the SV correctors are applied immediately to the echosounding data without further user interaction.

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Unknown Referred to as the "Nibbler"

Manufacturer	Unknown
Model	Referred to as the "Nibbler"
Description	The "Nibbler" is a foot-trip model clam shell style bottom sampler. This sampler is designed to collect unconsolidated sediments up to the size of small pebbles. The sampler is fabricated from sturdy bronze and stainless steel materials for trouble-free service in a marine environment. The "Nibbler" consists of a long threaded post surrounded by a strong compression spring that presses against the jaws at one end and an adjustable screw cap at the upper end. By turning this threaded cap the spring-compression is adjusted, changing the strength at which the jaws close. A shackle is attached through a hole on the top of the post and a line attached. Due to the small of this sampler, it may be deployed either by using a heavy duty fishing pole or by using a handline. Prior to deployment, the jaws are cocked open by manipulation of an internal triggering mechanism, internal to the jaws. Upon impact with the bottom, the tension is momentarily released on the clam shell jaws, disengaging the internal trigger, and allowing the spring-tensioned, hinged jaws to snap shut.

Figure 21: The "Nibbler", a foot-trip clam shell style bottom sampler.

A.8.1.2 AMS, Inc. 15 lb SST Dredge #445.10

Manufacturer	AMS, Inc.
Model	15 lb SST Dredge #445.10
Description	The AMS 15 lb SST Dredge is a Ponar type grab sampler, a commonly used sampler that is very versatile for all types of bottom sediments such as sand, gravel and clay. This modified Van Veen type self-tripping sampler features center hinged jaws and a spring loaded trigger pin that releases when the sampler makes impact with the bottom. The sampler's jaws are closed by the scissor action of the lever arms when the sampler is retrieved. The sampling area is 6" x 6". The sampler is constructed with stainless steel jaws and powder-coated carbon steel lever arms for corrosion resistance. It also includes an underlip attachment that cleans gravel from the jaws that would normally allow lateral loss of sample during retrieval. The top of the stainless steel sampling chamber has been cut with slits and covered with neoprene rubber flaps which allow water to flow through for a controlled descent and to reduce the frontal shock wave that may displace sediment as the dredge contacts the sample surface. This relatively lightweight model (1/8" stainless plate) is easily used from a small boat with nylon cable.

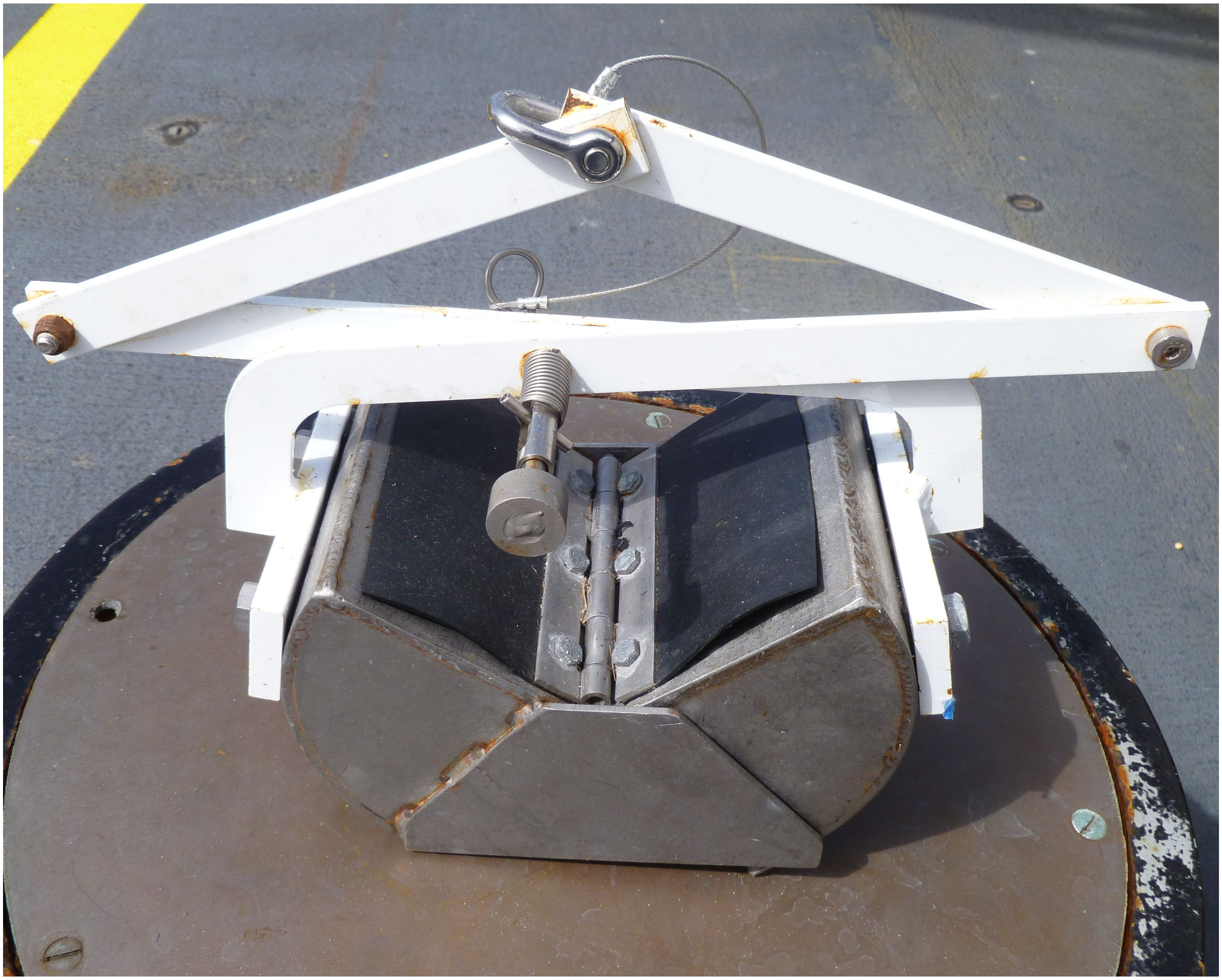

Figure 22: The AMS 15 lb SST Dredge #445.10 Ponar type grab sampler.

A.8.1.3 Unknown Van Veen style grab sampler

Manufacturer	Unknown
Model	Van Veen style grab sampler
Description	This Van Veen Grab Sampler is a hinged clamshell bucket instrument made out of galvanized steel. This sampler is designed to collect unconsolidated sediments up to the size of small pebbles. While letting the instrument down into the water, the two levers with buckets at their ends are spread like an open scissor. The levers are locked in this position by a hooked metal latch that is designed to drop down and unlock when hitting the

	seafloor. When the rope is pulled upward again, the two buckets close and grab a sample from the sea floor.

Figure 23: The Van Veen grab sampler configured ready to deploy.

B Quality Control

B.1 Data Acquisition

B.1.1 Bathymetry

B.1.1.1 Multibeam Echosounder

Reson SeaBat 7125-B shallow water multibeam data are monitored in real-time using the Reson 7K Control Center online bathymetry data display. Adjustable user parameters common for Reson systems are range scale, power, gain, and pulse width. These parameters were adjusted as necessary to ensure the best bathymetric data quality. Additionally, vessel speed was adjusted as necessary, and in accordance with the NOS Hydrographic Surveys Specifications and Deliverables and Draft Standing Project Instructions, to ensure the required along-track coverage for object detection.

For the Rainier's Kongsberg EM 710 system, 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 SWMB 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. 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. In the event of any holidays found in post-processing, either traditional holiday lines, small polygons, or exported CARIS BASE surface GeoTIFFs may be used to direct data acquisition to fill them in.

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.

B.1.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

B.1.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

B.1.2 Imagery

B.1.2.1 Side Scan Sonar

Rainier currently deploys Side-Scan Sonar (SSS) in two different configurations, hull-mounted on two survey launches and towed by Rainier herself. The hull-mounted configuration has the advantage of no requirement for a towing cable and associated hardware such as a winch and cable counter in addition to much easier maneuvering and towfish security since the instrument is not trailing far behind the survey platform on the end of a cable. But the hull-mounted configuration has the disadvantages of being limited to relatively shallow waters since the fish cannot be lowered to improve the grazing angle to the shallow angle preferred by SSS in addition to all of the hull motions being transferred to the fish as opposed to the towed configuration where these motion are greatly dampened or eliminated by the cable. Refraction issues caused by freshwater lenses or solar warming in the surface layers also plague hull-mounted configurations.

Side-scan sonar is a category of sonar system that can efficiently create an image of large areas of the sea floor. This imagery is used to detect obstructions on the seafloor that may be hazardous to shipping or otherwise worthy of charting in addition to potentially identifying what these obstructions are. Since the sonar should be maintained at an altitude of 8 - 20% of range scale during acquisition, the hull-mounted configuration in use by Rainier launches limits launch SSS to relatively shallow waters. Side-scan sonar is typically used in areas when the seafloor is generally flat or gradually sloping. Due to a much greater swath angle, side scan sonar can cover a given area faster than multibeam in shallow waters. This advantage disappears in deeper waters where the range scale limits the swath width of SSS. While SSS can be used to determine the relative height and position of a contact, MBES, or diver investigation must be later be used to ensure an accurate depth and position.

The SSS system consists of four transducers, two each port and starboard, mounted on a towfish which is towed from the ship’s A-Frame astern of the ship or mounted directly to the hull of a launch. The towfish must be positioned in such a manner as to ensure a specific altitude of the towfish off of the seafloor, which is 8% to 20% of the sonar range scale in use. Typical range scales are 50 meters, 75 meters, 100 meters, and 150 meters, which correspond to 4 to 10 meters, 6 to 15 meters, 8 to 20 meters, and 12 to 30 meters off of the sea floor, respectively. When towed by the ship, the altitude of the towfish is controlled ship’s speed and length of tow cable deployed astern of the ship.

Side-scan sonar is collected following a pre-planned set of parallel lines. The distance between these lines is based on the expected water depth and thus range scale while also allowing for a 20% overlap. Side scan sonar is typically used in conjunction with a MBES system, where the MBES can provide greater depths and cover the nadir gap. Due to the difference in swath width between SSS and MBES systems, this results in a survey with complete SSS coverage and “skunk stripes” of MBES coverage.

During side-scan data collection, the sonar operator monitors the image quality in real-time, looking features and ensuring data quality. When refraction is encountered there are a few options available. For towed systems, the cable-out can be adjusted to get the sonar above or below the layer causing the refraction. It is preferable to get the sonar below the refraction layer if safety and operational conditions permit. For hull mounted systems, the vessel may relocate to an area without refraction or adjust line spacing closer together to ensure overlap of “good” data.

Two choices are available for orienting the towfish in the hull mounted configuration, the “hull mounted” RMC message containing both ship position and heading in addition to the ZDA message or the “towed” Course Made Good (CMG) using the GGA, VTG, and ZDA messages. Rainier launches were initially configured by the recommended method of using the RMC message as outlined in the “Discover I SOP Rev 1.0”. Later experimenting demonstrated that the “towed” CMG method provides superior results and less smearing of the outer beam imagery in both the towed and hull mounted configurations. Rainier launches were reconfigured to use the “towed” CMG method on 8/11/2015. Although launch SSS imagery may lack the sharpness of data collected after the “towed” CMG method was implemented, the ability to discern and quantify contacts was not seriously impaired.

For Rainier’s EdgeTech SSS systems, Discover I acquisition software was used, collecting JSF formatted data in high speed mode at low frequency. XTF files were not collected since it was found that JSFs were easier to process and produced better results. A range scale of 100m and bottom tracking was used for depths less than 20m unless refraction issues forced a range scale reduction.

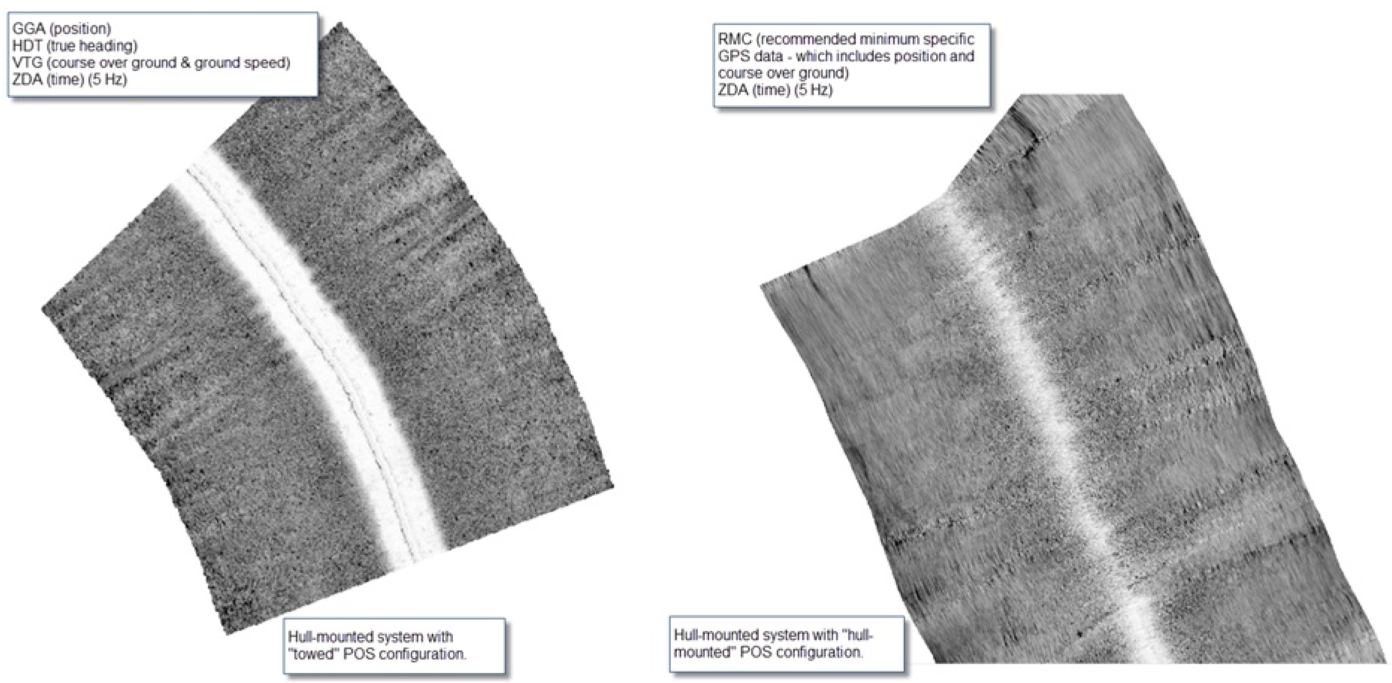

Figure 24: "Hull-mounted" vs "towed" configuration, the "towed" configuration gives superior results.

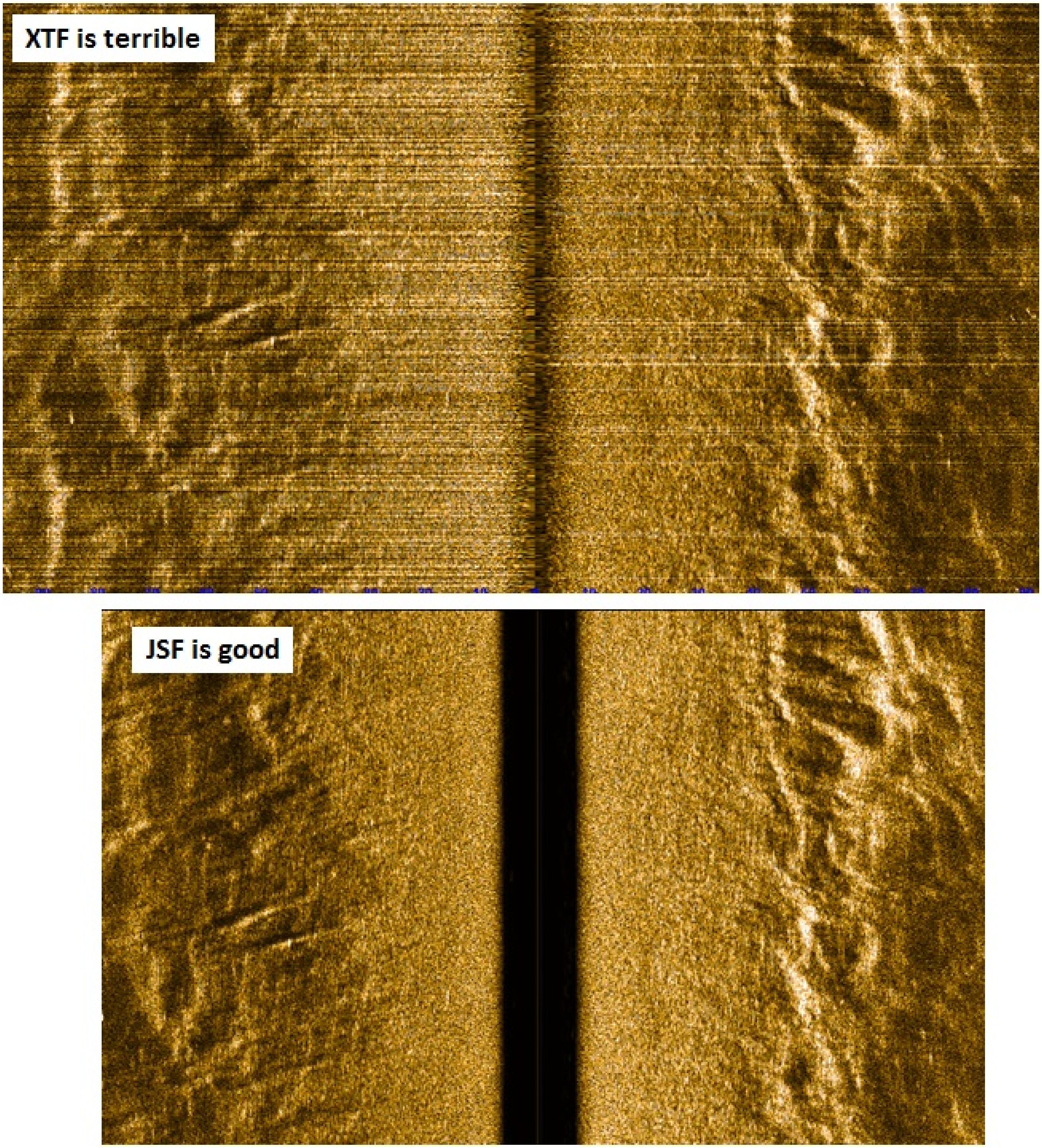

Figure 25: JSF format (good) vs XTF format (ugly), Rainier collects SSS data exclusively in JSF format.

B.1.2.2 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

B.1.3 Sound Speed

B.1.3.1 Sound Speed Profiles

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 the 2016 Olympic Coast project which contained charted depths in excess of 400 fathoms (~730m), Rainier was provided with the XBT probes 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.

B.1.3.2 Surface Sound Speed

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.

B.1.4 Horizontal and Vertical Control

B.1.4.1 Horizontal Control

Real-Time Differential GPS:

The Differential Global Positioning System (DGPS) is an augmentation to Global Positioning System that provides improved location accuracy, from the 15-meter nominal GPS accuracy to about 3 meters in case of Rainier’s implementation.

DGPS uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the GPS satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudo ranges and actual (internally computed) pseudo ranges. The United States Coast Guard (USCG) and Canadian Coast Guard (CCG) each run such systems in the

U.S. and Canada on the longwave radio frequencies between 285 kHz and 325 kHz near major waterways and harbors.

Each Rainier survey launch is equipped with a DGPS Beacon Receiver that acquires differential error correction messages (RTCM SC104 format) broadcast by US Coast Guard and feeds them to the Applanix POS/MVs to produce real time differentially corrected positions.

In some remote survey areas differential correctors from Coast Guard stations are not available or unreliable. As an alternative, POS/MV has the ability to be 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 2016 field season, only Rainier had her POS/MV configured to receive only WAAS correctors. Occasionally WAAS correctors were used on Rainier survey launches when difficulties were encountered keeping a lock on differential correctors from the US Coast Guard.

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.

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.

For a complete description of all equipment making up a base station, see section A.6.1.1 of this report.

Figure 26: A Rainier base station installed in Uganik Bay, Alaska.

B.1.4.2 Vertical Control

Vertical control data were not acquired.

B.1.5 Feature Verification

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 27: Survey skiff RA8 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.

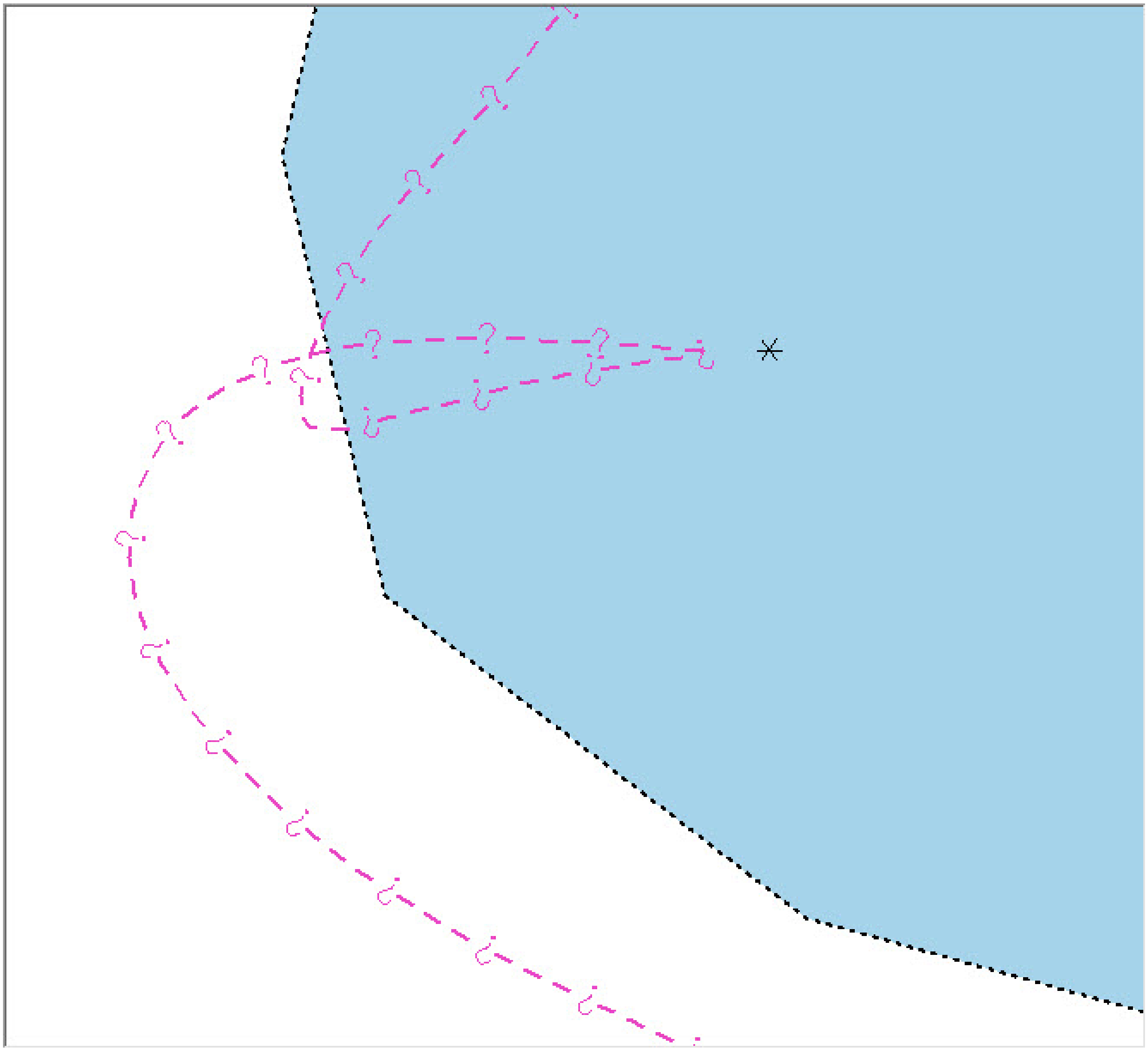

Figure 28: The magenta track-line collected in the field with a skiff and CARIS Notebook used to position a new rock.

B.1.6 Bottom Sampling

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

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

B.1.7 Backscatter

Current guidance from the Field Procedures Manual calls for field units to acquire and submit multibeam backscatter data whenever feasible.

Reson “snippets” imagery are recorded at acquisition and are present in the raw data, but not processed or analyzed. Snippet data contains the amplitude data of each individual sonar beam in a swath, but there are problems, well-documented in the hydrographic literature, that reduces the efficacy of processing these data.

Backscatter data are collected by default with the Rainier's EM710.

B.1.8 Other

No additional data were acquired.

B.2 Data Processing

B.2.1 Bathymetry

B.2.1.1 Multibeam Echosounder

Following acquisition, multibeam sonar data were processed either by using the CARIS HIPS and SIPS Batch Processor or by manually following the same steps as the batch processing script. The batch processor runs a user defined script which accomplishes the following standard tasks without user intervention:

1. Convert the “raw” Reson or SIS data to the HDCS data format.
2. Load True Heave (referred to as Delayed Heave in CARIS)
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 poor quality flags, (0 for Reson).
- Reject soundings with TPU greater than the horizontal and vertical error limits specified in the NOS Hydrographic Surveys Specifications and Deliverables:

  Horizontal Error > (5m + 5% of depth)
  Vertical Error > ±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 – As per the figure below and dependent upon the surface resolution.

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.

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 pallet selected is intended to aid swift navigation over previously surveyed areas in addition to highlighting shallow areas.

Depth Range Filtering	CUBE Surface Resolution	BASE surface Advanced Options Configuration
0-20 m	1 m	NOAA_1m
18-40 m	2 m	NOAA_2m
36-80 m	4 m	NOAA_4m
72-160 m	8 m	NOAA_8m
144-320m	16 m	NOAA_16m
288-> m	32 m	NOAA_32m

Figure 29: Depth range vs. CUBE surface resolution.

B.2.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not processed.

B.2.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not processed.

B.2.1.4 Specific Data Processing Methods

B.2.1.4.1 Methods Used to Maintain Data Integrity

See section B.2.1.1

B.2.1.4.2 Methods Used to Generate Bathymetric Grids

See section B.2.1.1

B.2.1.4.3 Methods Used to Derive Final Depths

Methods Used	Surface Computation Algorithms
Description	Rainier uses the CARIS CUBE BASE surface algorithms for the generation of all surfaces generated for final submission. The exact behavior of CUBE is determined by the values set in the CUBE parameters file, a xml file which can be selected by the user in the CARIS Tools --> Options --> Environment tab. The NOAA Office of

	Coast Survey (OCS) has created and provided a customized CUBE parameters file (CubeParams_NOAA.xml) with new CUBE parameters that are required for each grid resolution. During the creation of CUBE surfaces, the user is given the option to select parameter configurations based upon surface resolution which have been tuned to optimize the performance of the CUBE algorithm. The advanced options configuration is manipulated based on the grid resolution of the CUBE surface being generated.

B.2.2 Imagery

B.2.2.1 Side Scan Sonar

Side scan sonar imagery was not processed.

B.2.2.2 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not processed.

B.2.2.3 Specific Data Processing Methods

B.2.2.3.1 Methods Used to Maintain Data Integrity

The Reson 7125 systems aboard 2801, 2802, 2803 and 2804 acquire angle-independent pseudo SSS imagery. This SSS imagery is primarily used during processing of the multibeam sounding data to aid in determining whether anomalous soundings are true features or noise. It generally does not have sufficient resolution for small object detection, but the shape of objects and their strength of return can greatly increase the confidence in processing results.

B.2.2.3.2 Methods Used to Achieve Object Detection and Accuracy Requirements

n/a

B.2.2.3.3 Methods Used to Verify Swath Coverage

n/a

B.2.2.3.4 Criteria Used for Contact Selection

Criteria used for SSS contact selection conform to that found in section 6.1.3.2 of the HSSD, Significant Contacts.

B.2.2.3.5 Compression Methods Used for Reviewing Imagery

No compression methods were used for reviewing imagery.

B.2.3 Sound Speed

B.2.3.1 Sound Speed Profiles

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’.

B.2.3.1.1 Specific Data Processing Methods

B.2.3.1.1.1 Caris SVP File Concatenation Methods

CARIS SVP files are concatenated on a sheet wide basis.

B.2.3.2 Surface Sound Speed

Surface sound speed data were not processed.

B.2.4 Horizontal and Vertical Control

B.2.4.1 Horizontal Control

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).

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.

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 WGS84.

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.

B.2.4.2 Vertical Control

For the 2016 field season, Rainier was not required to install any tide gauges.

B.2.5 Feature Verification

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.

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 2016 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.

B.2.6 Backscatter

Although no formal processing of backscatter data were performed, backscatter data were converted per 2016 HSSD specification to spot check and ensure that it was being properly logged. No processed backscatter data is included with the data submission but all raw backscatter data are submitted to PHB as part of the regular sheet submission process.

B.2.7 Other

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.

Final data processing and analysis is the responsibility of the Survey Team. While "ping-by-ping" data editing is not required, the Team will review the survey in its entirety to ensure that the final products reflect observed conditions to the standards set by the relevant OCS guidance. Bathymetric surfaces are reviewed with the best available correctors applied to ensure that all data quality problems are identified and resolved if possible, and all submerged features are accurately represented. Shoreline verification (if applicable) and feature data are reviewed in the context of this bathymetry. Survey documentation (including the Descriptive Report) is generated in conjunction with this review process.

B.3 Quality Management

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”. In the case of a survey where the high points of many features (i.e. a boulder field) are not being captured by the CUBE surface, the hydrographer may decide to produce higher resolution CUBE surfaces to ensure that these features are being honored. Any such deviations from standard procedures will be noted in that survey’s Descriptive Report.

At the time of this report, Coast Survey has not approved multiple resolution BASE surfaces as a final deliverable. Although these surfaces are acceptable for field use, the algorithm produces artifacts at the resolution steps that are unsuitable for a final product. To circumvent this problem, single resolution CUBE surfaces are generated to be “cookie cut” and then reassembled to create the final CUBE surface from which depths are derived. Multiple CUBE surfaces are gridded using different resolutions for different depth ranges as defined in section 5.2.2.2 of the HSSD.

Under ideal circumstances, gridding should be done at the finest resolution that the data density will support. This theoretical maximum resolution was historically defined as three times the beam footprint size for a particular echosounder and depth combination. Current guidance (HSSD 5.2.2.2) states that 95% of the nodes in a cube surface shall contain at least 5 soundings per node. This minimum density of 5 soundings per node has experimentally been shown to be adequate to represent the depth of the seafloor while not being strongly influenced by a single erroneous sounding.

To meet the required sounding density, Rainier adheres to the table of resolutions and depth ranges as defined in HSSD which are based on practical experience in “typical” survey areas, and a working knowledge of bottom coverage capabilities of each echo sounding system currently in use throughout the fleet. These resolutions are also based on assumed sonar system selections for each depth regime and practical data processing limitations. Deeper areas are gridded at a coarser resolution than shoaler areas where the data density is greater.

With the advent of the CARIS CSAR framework and multi-threaded CUBE processing implemented in CARIS HIPS and SIPS, it is practical to create a surfaces that cover an entire survey. All resolution-specific CUBE surfaces are created as needed. CUBE surface resolutions are described for each survey in the Descriptive Report.

Each resolution-specific CUBE surface is named according to the following convention:

<Survey registry number>_<Sounding Type>_<units of resolution>_Vertical Datum>

(EX: “H12345_MB_2m_MLLW” is the two-meter resolution surface of survey H12345 referenced to MLLW)

Once the collection of CUBE surfaces accurately represent the surveyed bottom and it is certain that no further edits will be made, each CUBE surface is finalized using the resolution as defined in section 5.2.2.2 of the HSSD. All finalized CUBE surfaces are then combined at the coarsest resolution created for the data set to produce the final combined CUBE surface. The final combined CUBE surface is named by the following convention; Hxxxxx_Final_Combined.

In order to extract data density statistics from a given sheet, each finalized surface is run through the Pydro Finalized CSAR Surface Compliance Tool. The program uses the Depth, Uncertainty, Density and an optional computed TVU QC layers from finalized BASE surfaces in the CARIS Spatial Archive file format (.csar) to create five or six plot files in PNG format: 1) Uncertainty Standards, 2) Object Detection Coverage, 3) Depth Distribution, 4) Node Depth vs. Sounding Density, 5) Node Depth vs. TVU QC (all data), and an optional 6) Node Depth vs. TVU QC < 1.0 – which is created if different from the "all data" plot in 5. Plots for Uncertainty Standards and Object Detection Coverage are inserted into the DR. If 95% of the nodes have 5 soundings per node a simple statement to that effect was added to the DR, otherwise an image of sounding data density is included in the DR.

The final CUBE surfaces are sun-illuminated from different angles and examined for coverage and as a final check for systematic errors such as tide, sound velocity, or attitude and/or timing errors. The final CUBE surface submitted serves to demonstrate that both SWMB coverage requirements are met and that systematic errors have been examined for quality-assurance purposes.

Another method to check the quality of sounding data prior to submission is the Pydro QCTool "flier finder". This software scans the BASE surface for potential anomalous grid data. Lowering the flier height value will increase the sensitivity of the flier finder, resulting in more nodes being flagged. Fliers are then exported as .000 S-57 files that can be imported into CARIS HIPS or BDB to aid in further cleaning. If desired, the user can set a new tolerance ("Flier height") and rerun Flier finder.

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. From these two surfaces, a surface difference was generated (at a 1 meter resolution). Statistics were then derived from the difference surface and documented within the Descriptive Report for each survey.

B.4 Uncertainty and Error Management

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.

• 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 face Reson 7125. A Reson SVP 70 is mounted on Rainier to provide correctors for the EM710. 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.

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 Reson 7125 and Konsgberg 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.

B.4.1 Total Propagated Uncertainty (TPU)

B.4.1.1 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.

B.4.1.2 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 “2016 HVF summary” included with this report.

B.4.1.3 TPU Values

Vessel	2801_Reson7125_HF_512
Echosounder	Reson SeaBat 7125-B 400 kilohertz

TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude
			0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position		1.000 meters
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.233 degrees
		Pitch	0.268 degrees
		Roll	0.268 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2801_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125-B 200 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude
			0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position		1.000 meters

	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.192 degrees
		Pitch	0.353 degrees
		Roll	0.353 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2802_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125 SV2 400 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude 0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters

	MRU Alignment	*Gyro*	0.181 degrees
		Pitch	0.213 degrees
		Roll	0.213 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2802_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125 SV2 200 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude
			0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.181 degrees
		Pitch	0.213 degrees
		Roll	0.213 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2803_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125-B 400 kilohertz		

TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude 0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.335 degrees
		Pitch	0.248 degrees
		Roll	0.248 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2803_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125-B 200 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude 0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	

	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.559 degrees
		Pitch	0.141 degrees
		Roll	0.141 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2804_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125 SV2 400 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude
			0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters

	MRU Alignment	*Gyro*	0.172 degrees
		Pitch	0.151 degrees
		Roll	0.151 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	2804_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125 SV2 200 kilohertz		
TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude
			0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.010 meters
		y	0.010 meters
		z	0.010 meters
	MRU Alignment	*Gyro*	0.172 degrees
		Pitch	0.151 degrees
		Roll	0.151 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.020 meters
		Delta Draft	0.010 meters
Vessel	S221_Simrad-EM710_ICE		
Echosounder	Kongsberg Simrad EM710 ½°x 1° 100 kilohertz		

TPU Standard Deviation Values	*Motion*	*Gyro*	0.020 degrees
		Heave	5.000 % Amplitude 0.050 meters
		Pitch	0.020 degrees
		Roll	0.020 degrees
	Navigation Position	1.000 meters	
	Timing	*Transducer*	0.005 seconds
		Navigation	0.005 seconds
		Gyro	0.005 seconds
		Heave	0.005 seconds
		Pitch	0.005 seconds
		Roll	0.005 seconds
	Offsets	*x*	0.002 meters
		y	0.002 meters
		z	0.002 meters
	MRU Alignment	*Gyro*	0.036 degrees
		Pitch	0.069 degrees
		Roll	0.069 degrees
	Vessel	*Speed*	0.080 meters/second
		Loading	0.025 meters
		Draft	0.021 meters
		Delta Draft	0.010 meters

B.4.2 Deviations

There were no deviations from the requirement to compute total propagated uncertainty.

C Corrections To Echo Soundings

C.1 Vessel Offsets and Layback

C.1.1 Vessel Offsets

C.1.1.1 Description of Correctors

Vessel offset correctors are the values used to describe the location of all hydrographic sensors in relation to a defined reference point. These values are needed to compute sensor lever arms required to correct for vessel orientation and ultimately produce the final geographic position for every sounding collected.

Included with this DAPR is the “2016 HVF summary” report. This report is a compilation of vessel reports for all of the survey platforms used during the 2016 field season. These vessel reports are created by the CARIS HIPS and SIPS Vessel Editor and include values used for depth sensor bias angles, sensor offset and time corrections, dynamic draft, TPU values, SVP sensor offset and mounting angle, and waterline values.

C.1.1.2 Methods and Procedures

For Rainier survey launches, all vessel offset values are stored in the CARIS HVF. The POS MV IMU is defined as Reference Point (RP). Ideally the RP should be as close as possible to the center of rotation for the vessel as feasible and this fact was taken into account when positioning the IMU. Since the IMU is the source for all launch heave, pitch, roll, gyro, and navigation values, all of these sensors have X-Y-Z values of 0,0,0. Only Transducer 1 and SVP 1, the sonar unit, requires non-zero offset values entered.

For Rainier the situation is much more complicated since problems with heave occur if the RP is defined as the IMU. Due to this the RP was put at 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 offsets 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.

All actual offset values were surveyed and verified as described in section A.1 of this report.

Vessel offset correctors may also be found in the “2016 HVF summary” included with this report.

C.1.1.3 Vessel Offset Correctors

Vessel	2801_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125-B 400 kilohertz		
Date	2016-05-18		
Offsets	*MRU to Transducer*	*x*	0.002 meters
		y	0.057 meters
		z	0.475 meters
		x2	N/A
		y2	N/A
		z2	N/A

	Nav to Transducer	*x*	0.002 meters
		y	0.057 meters
		z	0.475 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2801_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125-B 200 kilohertz		
Date	2016-05-18		
Offsets	*MRU to Transducer*	*x*	0.002 meters
		y	0.054 meters
		z	0.475 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Nav to Transducer	*x*	0.002 meters
		y	0.054 meters
		z	0.475 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2802_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125 SV2 400 kilohertz		
Date	2016-05-16		
Offsets	*MRU to Transducer*	*x*	-0.004 meters
		y	0.045 meters
		z	0.474 meters
		x2	N/A
		y2	N/A
		z2	N/A

	Nav to Transducer	*x*	-0.004 meters
		y	0.045 meters
		z	0.474 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2802_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125 SV2 200 kilohertz		
Date	2016-05-16		
Offsets	*MRU to Transducer*	*x*	-0.004 meters
		y	0.045 meters
		z	0.474 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Nav to Transducer	*x*	-0.004 meters
		y	0.045 meters
		z	0.474 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2803_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125-B 400 kilohertz		
Date	2016-05-16		
Offsets	*MRU to Transducer*	*x*	-0.003 meters
		y	0.031 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A

	Nav to Transducer	*x*	-0.003 meters
		y	0.031 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2803_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125-B 200 kilohertz		
Date	2016-06-06		
Offsets	*MRU to Transducer*	*x*	-0.003 meters
		y	0.030 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Nav to Transducer	*x*	-0.003 meters
		y	0.030 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2804_Reson7125_HF_512		
Echosounder	Reson SeaBat 7125 SV2 400 kilohertz		
Date	2016-05-19		
Offsets	*MRU to Transducer*	*x*	0.009 meters
		y	0.025 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A

	Nav to Transducer	*x*	0.009 meters
		y	0.025 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	2804_Reson7125_LF_256		
Echosounder	Reson SeaBat 7125 SV2 200 kilohertz		
Date	2016-05-19		
Offsets	*MRU to Transducer*	*x*	0.009 meters
		y	0.025 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Nav to Transducer	*x*	0.009 meters
		y	0.025 meters
		z	0.481 meters
		x2	N/A
		y2	N/A
		z2	N/A
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	N/A
Vessel	S221_Simrad-EM710_ICE		
Echosounder	Kongsberg Simrad EM710 ½°x 1° 100 kilohertz		
Date	2014-01-01		
Offsets	*MRU to Transducer*	*x*	0.000 meters
		y	0.000 meters
		z	0.000 meters
		x2	0.000 meters
		y2	0.000 meters
		z2	0.000 meters

	Nav to Transducer	*x*	0.000 meters
		y	0.000 meters
		z	0.000 meters
		x2	0.000 meters
		y2	0.000 meters
		z2	0.000 meters
	Transducer Roll	*Roll*	0.000 degrees
		Roll2	0.000 degrees

C.1.2 Layback

C.1.2.1 Description of Correctors

Layback correctors are the values used to describe the location of side scan sonar sensors in relation to a defined reference point. In the case of hull mounted sonar units, the values are directly referenced to the fish itself. In the case of Rainier which actually towed the sonar fish, the values are referenced to the tow-point on the ship's A-frame. The coordinates of this tow-point in addition the length of cable out are used to calculate the position of the side-scan sonar fish. These values are needed to correctly geo-reference imagery collected by the side scan sonar unit.

C.1.2.2 Methods and Procedures

For Rainier and her survey launches, layback values are stored in CARIS HVFs created for each vessel that collected side-scan sonar data. The POS MVs IMU is defined as Reference Point (RP). Separate HVF files were created for both low and high frequency.

All actual offset values were surveyed and verified as described in section A.1 of this report.

Layback correctors may also be found in the "2016 HVF summary" included with this report.

C.1.2.3 Layback Correctors

Vessel	2802_Edgetech4200_MP_Hull_HF		
Echosounder	Edgetech 4200 600 kilohertz		
Date	2015-06-16		
Layback	*Towpoint*	*x*	0.505 meters
		y	-0.727 meters
		z	0.661 meters
	Layback Error	0.000 meters	

<table>
<tr><td>Vessel</td><td colspan="3">2802_Edgetech4200_MP_Hull_LF</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200 300 kilohertz</td></tr>
<tr><td>Date</td><td colspan="3">2015-06-16</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>0.505 meters</td></tr>
<tr><td>y</td><td>-0.727 meters</td></tr>
<tr><td>z</td><td>0.661 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.000 meters</td></tr>
<tr><td>Vessel</td><td colspan="3">2804_Edgetech4200_MP_Hull_HF</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200 600 kilohertz</td></tr>
<tr><td>Date</td><td colspan="3">2015-06-15</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-0.505 meters</td></tr>
<tr><td>y</td><td>-0.727 meters</td></tr>
<tr><td>z</td><td>0.661 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.000 meters</td></tr>
<tr><td>Vessel</td><td colspan="3">2804_Edgetech4200_MP_Hull_LF</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200 300 kilohertz</td></tr>
<tr><td>Date</td><td colspan="3">2015-06-15</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-0.505 meters</td></tr>
<tr><td>y</td><td>-0.727 meters</td></tr>
<tr><td>z</td><td>0.661 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">0.000 meters</td></tr>
<tr><td>Vessel</td><td colspan="3">S221_Edgetech4200_MP_HF</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200 600 kilohertz</td></tr>
<tr><td>Date</td><td colspan="3">2015-08-14</td></tr>
<tr><td rowspan="4">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-0.090 meters</td></tr>
<tr><td>y</td><td>-50.995 meters</td></tr>
<tr><td>z</td><td>-6.682 meters</td></tr>
<tr><td>Layback Error</td><td colspan="2">-7.000 meters</td></tr>
<tr><td>Vessel</td><td colspan="3">S221_Edgetech4200_MP_LF</td></tr>
<tr><td>Echosounder</td><td colspan="3">Edgetech 4200 300 kilohertz</td></tr>
<tr><td>Date</td><td colspan="3">2015-08-14</td></tr>
<tr><td rowspan="3">Layback</td><td rowspan="3">Towpoint</td><td>x</td><td>-0.090 meters</td></tr>
<tr><td>y</td><td>-50.995 meters</td></tr>
<tr><td>z</td><td>-6.682 meters</td></tr>
</table>

	Layback Error	-7.000 meters

C.2 Static and Dynamic Draft

C.2.1 Static Draft

C.2.1.1 Description of Correctors

Static draft correctors are the z-values used to describe the difference between the measured waterline on the hull and the reference point while the vessel is at rest. Since the distance between the reference point and transducers is known, it is elementary to derive the difference between the water line and the transducer. This value is required to correct for the draft of the transducer when computing the corrected water depths.

C.2.1.2 Methods and Procedures

For Rainier survey launches, all static draft corrector values are stored in the CARIS HVF as the waterline value. This value is measured during the HSRR, as described in section A.1. of this report, and used for the entire field season. It is assumed that this value remains relatively unchanged since little difference in draft has been seen under various fuel loading conditions.

For Rainier, static draft corrector values are entered in the Kongsberg SIS Installation Parameters window. Unlike survey launches, loading conditions on the ship, particularly fuel and launches, does have a significant influence on static draft. To compensate, during the Kongsberg start up procedure static draft values are measured as described in section A.1 of this report. In addition to being entered into the SIS Installation Parameters window, waterline values are also entered in the CARIS HVF. This Waterline value in CARIS will only be used during Sound Velocity Correction. The Apply switch is also set to “No”. If it is set to “Yes”, the waterline value will be applied twice, once in SIS and again in Merge.

Static draft correctors may also be found in the “2016 HVF summary” included with this report.

C.2.2 Dynamic Draft

C.2.2.1 Description of Correctors

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 2016 field season. See the report “FA_classHSL_DynamicDraft” attached to this document for more information.

C.2.2.2 Methods and Procedures

DDSSM for all four Rainier launches were determined using an average of historic values. A singe dynamic draft table was determined and applied to all launches for the 2016 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 “2016 HVF summary” included with this report.

C.2.2.3 Dynamic Draft Correctors

<table>
<tr><td>Vessel</td><td>All Rainier Jensen survey launches</td></tr>
<tr><td>Date</td><td>2016-03-21</td></tr>
<tr><td>Dynamic Draft Table</td><td><table><tr><td>Speed</td><td>Draft</td></tr><tr><td>0.0</td><td>0.00</td></tr><tr><td>0.5</td><td>-0.01</td></tr></table></td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><th>Speed</th><th>Draft</th></tr>
<tr><td>1.0</td><td>-0.01</td></tr>
<tr><td>1.5</td><td>0.00</td></tr>
<tr><td>2.0</td><td>0.02</td></tr>
<tr><td>2.5</td><td>0.03</td></tr>
<tr><td>3.0</td><td>0.05</td></tr>
<tr><td>3.5</td><td>0.05</td></tr>
<tr><td>4.0</td><td>0.05</td></tr>
<tr><td>4.5</td><td>0.03</td></tr>
<tr><td>5.0</td><td>0.00</td></tr>
<tr><td>5.5</td><td>-0.05</td></tr>
<tr><td>6.0</td><td>-0.10</td></tr>
<tr><td>6.5</td><td>-0.14</td></tr>
<tr><td>7.0</td><td>-0.20</td></tr>
</table>
</td></tr>
<tr><td>Vessel</td><td>S221 (Rainier)</td></tr>
<tr><td>Date</td><td>2013-05-01</td></tr>
<tr><td>Dynamic Draft Table</td><td>
<table>
<tr><th>Speed</th><th>Draft</th></tr>
<tr><td>0.0</td><td>0.00</td></tr>
<tr><td>0.5</td><td>0.02</td></tr>
<tr><td>1.0</td><td>0.03</td></tr>
<tr><td>1.5</td><td>0.04</td></tr>
<tr><td>2.0</td><td>0.04</td></tr>
<tr><td>2.5</td><td>0.05</td></tr>
<tr><td>3.0</td><td>0.07</td></tr>
<tr><td>3.5</td><td>0.08</td></tr>
<tr><td>4.0</td><td>0.11</td></tr>
<tr><td>4.5</td><td>0.14</td></tr>
<tr><td>5.0</td><td>0.17</td></tr>
<tr><td>5.5</td><td>0.20</td></tr>
<tr><td>6.0</td><td>0.23</td></tr>
<tr><td>6.5</td><td>0.25</td></tr>
<tr><td>7.0</td><td>0.26</td></tr>
</table>
</td></tr>
</table>

C.3 System Alignment

C.3.1 Description of Correctors

Heave, pitch, roll and heading, including attitude biases and navigation timing errors.

For Rainier (S221):

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.

For survey launches 2802 & 2804 (SeaBat 7125 SV2):

As part of the annual HSRR, Rainier conducted MBES calibration tests for each individual multibeam system on all survey launches. Although the Sea Bat 7125 SV2 multibeam system is a dual frequency system, it uses the same transducer for both frequencies and therefore the test values obtained for one frequency should match those of the other frequency. The procedure used follows that outline in section 1.5.5.1 of the 2014 Field Procedures Manual. Timing bias was assumed to be zero. Pitch and yaw bias was determined using a target on the seafloor. And finally, roll bias was determined using the standard flat bottom method.

For survey launches 2801 & 2803 (Sea Bat 7125-B):

As part of the annual HSRR, Rainier conducted MBES calibration tests for each individual multibeam system on all survey launches. The Sea Bat 7125-B multibeam system is a dual frequency system utilizing a separate transducer for each frequency and thus requiring an individual test for each frequency. The procedure used follows that outline in section 1.5.5.1 of the 2014 Field Procedures Manual. Timing bias was assumed to be zero. Pitch and yaw bias was determined using a target on the seafloor. And finally, roll bias was determined using the standard flat bottom method.

C.3.2 Methods and Procedures

For all survey launches:

Data was converted in CARIS HIPS using a HVF file with 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. These averaged values were established as the final correctors and were added to 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.

2016 Rainier system alignment issues:

As part of the HSRR, Rainier conducted a GAMS calibration of the ship's POS MV system while in transit back to Newport, Oregon after a winter dry-dock at the Vallejo shipyard in California. After several weeks of additional maintenance work on the ship in Newport, Rainier departed for the 2016 field season and was immediately put to work on an offshore survey in the Olympic Coast National Marine Sanctuary. Due to both time constraints caused by a late departure and the lack of a suitable evaluation area, a patch test was not conducted for the ship prior to survey operations. The intent was to run with the previous year's patch values until a proper patch test could be conducted, and then apply these new values to all data collected in 2016.

Unfortunately data collected for the Olympic Coast project revealed a marked shift in data between adjacent lines. A preliminary analysis revealed that a -3° yaw bias entered into the HVF seemed to fix the problem. HSTP was notified of the issue and requested that three adjacent lines showing the yaw issue be sent to them along with the applicable POS/MV files.

While waiting to hear back from HSTP Rainier performed another GAMS calibration and a patch test off northern Kodiak Island, the -3° yaw bias persisted.

HSTP analysis of real-time navigation vs SBET gave a consistent difference of 3 degrees. The persistence of this 3 degree yaw error in spite of a new GAMS calibration lead to a working theory that the GAMS calibration was somehow producing the wrong answer, perhaps due to overly-tight tolerances. In addition, the analysis of the EM710 coordinate and offsets revealed that the roll and yaw values entered in the 710 Rx (SVP 2 in the HVF) were inadvertently reversed in the original 2014 configuration of the EM710. These reversed values are likely the root cause of what at the time was an unexplained minor tweak in the HVF roll value dating back to 2014.

To fix all of these issues, HSTP recommended adjusting all of the coordinates and offsets to what should have been entered in 2014. In addition it was recommended than no bias values should be entered into either the HVF or SIS; rather these values were all entered into the POS. GAMS vector values were derived by post processing GAMS. Rainier followed these recommendations and conducted a new patch test. Since all of the bias values statistically had a value of zero, it was determined that the GAMS vector values and the IMU w.r.t. frame in the POS were all "correct" and all values were retained.

The 2016 HVF for DN 178 retains the -2.95 yaw and 0.095 roll bias values respectively caused by the faulty GAMS calibration and the reversed roll and yaw values. After implementing all of HSTP's recommendations, a new patch test confirmed the all bias values were now zero, and this is reflected in the HVF starting on DN 179 that has zero for roll, pitch and yaw bias values.

System alignment correctors may also be found in the “2016 HVF summary” included with this report.

C.3.3 System Alignment Correctors

Vessel	2801_Reson7125_HF_512	
Echosounder	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz	
Date	2016-05-18	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	-0.737 degrees
	Roll	-0.300 degrees
	Yaw	0.528 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.4 System Alignment Correctors

Vessel	2801_Reson7125_LF_256	
Echosounder	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
Date	2016-05-18	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	-0.940 degrees
	Roll	-0.279 degrees
	Yaw	0.490 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.5 System Alignment Correctors

Vessel	2802_Reson7125_HF_512
Echosounder	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz
Date	2016-05-16

Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	-1.156 degrees
	Roll	-0.233 degrees
	Yaw	0.404 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.6 System Alignment Correctors

Vessel	2802_Reson7125_LF_256	
Echosounder	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
Date	2016-05-16	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	-1.156 degrees
	Roll	-0.233 degrees
	Yaw	0.404 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.7 System Alignment Correctors

Vessel	2803_Reson7125_HF_512	
Echosounder	Reson SeaBat 7125 (400kHz 512 Beams) 400 megahertz	
Date	2016-05-16	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	0.158 degrees
	Roll	0.010 degrees
	Yaw	-0.506 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.8 System Alignment Correctors

Vessel	2803_Reson7125_LF_256	
Echosounder	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
Date	2016-05-16	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	0.348 degrees
	Roll	-0.015 degrees
	Yaw	0.628 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.9 System Alignment Correctors

Vessel	2804_Reson7125_HF_512	
Echosounder	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz	
Date	2016-05-19	
Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	0.611 degrees
	Roll	0.828 degrees
	Yaw	-0.932 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.3.10 System Alignment Correctors

Vessel	2804_Reson7125_LF_256
Echosounder	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz
Date	2016-05-19

Patch Test Values	*Navigation Time Correction*	0.000 seconds
	Pitch	0.611 degrees
	Roll	0.828 degrees
	Yaw	-0.932 degrees
	Pitch Time Correction	0.000 seconds
	Roll Time Correction	0.000 seconds
	Yaw Time Correction	0.000 seconds
	Heave Time Correction	0.000 seconds

C.4 Positioning and Attitude

C.4.1 Description of Correctors

Heave, pitch, roll and heading, including attitude biases and navigation timing errors.

C.4.2 Methods and Procedures

Attitude and Heave data were measured with the sensors described in Section A, and applied in post-processing during SVP Correct and Merge in CARIS HIPS.

Rainier and all of her SWMB equipped survey launches utilize a heave filter integration method known as "TrueHeave" as described in Section 3 of the 2014 Field Procedures Manual. This dramatically reduces the filter settling time as compared to the traditional heave filter, almost completely eliminating the need for steadying up on lines before logging can begin.

TrueHeave data were logged throughout the survey day, independent of line changes. A new POS file need be created only in the event that the acquisition computer crashes. Every "POS" file is named in such a manner to be easily identifiable with the applicable year, DN and VN (ex: 2015_214_2802.000). TrueHeave files are transferred to the "POSMV" folder of the CARIS preprocessed data drive (ex: H:\2015 Data\OPR-S327-RA-15_Kotzebue_Sound\H12820\POSMV\2802(RA-5)\DN214 contains TrueHeave data acquired by vessel 2802 on day number 214 for sheet H12820) for later submission. In the event of computer crashes, multiple POS files have their names appended with "A", "B", and so on in the order they were collected. After regular CARIS data conversion, the TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw data. TrueHeave is actually applied to the data, if the checkbox is marked, during the sound velocity correction process.

It is standard procedure to begin logging the POS MV Applanix .000 file at least 5 minutes before starting bathymetric data acquisition and letting it run for at least 5 minutes afterward. Although the filter that produces the true heave values by looking at a long series of data to create a baseline needs only 3 minutes before and after the acquisition of bathymetric data, SBET processing which uses the same .000 file requires logging for 5 minutes before and after bathymetric acquisition.

It is important not log the POS MV Applanix .000 file through UTC midnight on Saturdays. At this time the GPS seconds of the week reset. Neither POSPac nor CARIS are able to use this data and the result is a holiday in the coverage data. Hypack/Hysweep and POS MV file logging must be stopped before UTC midnight. After UTC midnight a new POS file is started with the new day number.

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in section “C” of this report.

All Rainier survey launch offsets, dynamic draft correctors, and system bias values are contained in CARIS HIPS Vessel Files (HVFs) and were created using the program Vessel Editor in CARIS. These offsets and biases are applied to the sounding data during processing in CARIS.

Due to the workaround procedures affecting the Kongsberg EM710 implementation aboard Rainier as detailed section B.1.1.1 of this report, offsets, dynamic draft correctors, and system bias values are spread out between the ship's HVF, SIS configuration and POS/MV configuration.

C.5 Tides and Water Levels

C.5.1 Description of Correctors

Water level correctors are typically applied to Rainier hydrographic data by one of two methods;

1) discrete zones by way of a CO-OPS supplied zone definition file (.zdf) or by
2) TCARI, the Tidal Constituent And Residual Interpolator by way of a CO-OPS supplied TCARI grid file (.tc).

Depending on vertical control requirements, CO-OPS may require the installation of subordinate tide gauge(s) in the project area. If subordinate tide gauge(s) are used, station packages are sent to CO-OPS following installation, performance of bracketing levels, and removal as required by Section 4.6.1 of NOAA HSSD. For the 2016 field season, Rainier was not required to install any tide gauges.

Upon completion of a sheet, Pydro is used to generate a request for final tides which includes a times of hydrography abstract and mid/mif tracklines. This request is submitted via email to Final.Tides@noaa.gov with the project number and sheet number in the subject line of the email. Once CO-OPS receives this request, a review of the times of hydrography, final tracklines, and six-minute water level data from all applicable water level gauges is conducted.

After this review if there are no issues, CO-OPS will send a notice indicating that the tidal zoning scheme (.zdf or .tc) sent with the project instructions has been approved for final zoning. If there are discrepancies, CO-OPS will make the appropriate adjustments and forward a revised tidal zoning scheme to the ship for final processing.

DISCRETE ZONES

For daily processing, soundings are reduced to Mean Lower-Low Water (MLLW) using predicted waterlevels files supplied with the project instructions. The predicted water level data are applied to the survey depths in CARIS using height ratio and time correctors from a preliminary CO-OPS provided zone definition file. No real-time tide or water level corrections of soundings took place in during data acquisition.

After the conclusion of data acquisition, CO-OPS will either accept preliminary zoning as the final zoning or supply a revised zoning file. Verified six-minute water level data is downloaded for the operating station(s) providing water level reducers for the project as listed in section 1.3.1 of the Water Level Instructions. Once all required water levels are downloaded, they are loaded from the main menu in CARIS HIPS, Process > Load Tide… and the zdf file is selected.

TCARI

To reduce soundings to Mean Lower-Low Water (MLLW), the TCARI grid file sent from CO-OPS is loaded into Pydro. Once in Pydro the TCARI grid may be examined along with the list of tide stations that affect it. TCARI utilizes all tide stations in the project area (historical and currently operating) for harmonic constants and datums. Only those stations selected in the residual column are used for residuals. Residuals are the difference between observed water levels and predicted water levels due to non-tidal components such as meteorological effects. The TCARI Project Instructions sent for each project list the stations required for residuals that must be downloaded from the CO-OPS website.

For initial daily processing, soundings were reduced to Mean Lower-Low Water (MLLW) using predicted water levels from the preliminary TCARI file supplied with the project instructions. Applying tides with the TCARI file by itself without loading any water level data simply applies predicted tides without any of the residual correctors that observed water levels would provide.

After the conclusion of data acquisition, verified six-minute water level data for operating stations supplying residuals as listed in section 1.3.6 of the Water Level Instructions are downloaded on the MLLW datum in meters and UTC. TCARI tides are loaded and applied directly to CARIS HDCS data using Pydro. Once all required water levels are downloaded, they are loaded from the main menu bar, Tides > Load WL Data. Tide reducers are generated for HDCS bathymetry from the main tool bar, Tides >CARIS TCARI Tide>Load TCARI Tide in HIPS PVDLs. At this time HDCS data is selected by project, vessel, and day with individual lines selected with the Descend/Confirm button. TCARI then creates new “Tide”, “TideLineSegments”, and “TideTmIDX” files for each line of bathymetry. Once TCARI created the new tide files, the lines were re-merged in CARIS to force the changes to take effect.

TCARI automatically calculates the error associated with water level interpolation. This error is incorporated into the residual/harmonic solutions and included in the Total Propagated Uncertainty (TPU) for the survey. Although the uncertainty values input into TCARI model are 2-sigma, Pydro automatically supplies 1-sigma values to CARIS when computing uncertainty.

C.5.2 Methods and Procedures

After the conclusion of data acquisition, water levels were applied to the soundings of each individual project as follows:

M-N908-RA-16, IOCM Olympic Coast NMS Mapping Project, Washington

Preliminary water levels are generated using the CO-OPS supplied Tidal Constituent And Residual Interpolator (TCARI) file RA1601IOCM.tc and Preliminary/Verified water levels from Westport, WA (944-1102), LaPush, WA (944-2396), Neah Bay, WA (944-3090) and Port Angeles, WA (944-4090). No subordinate stations were required for project M-N908-RA-16.

OPR-P136-RA-16, North Coast of Kodiak Island, Alaska

Preliminary water levels are generated using the CO-OPS supplied Tidal Constituent And Residual Interpolator (TCARI) file P136RA2016.tc and Preliminary/Verified water levels from Seldovia, AK (945-5500). No subordinate stations were required for project OPR-P136-RA-16.

C.6 Sound Speed

C.6.1 Sound Speed Profiles

C.6.1.1 Description of Correctors

Sound velocity profiles for Rainier survey launches were acquired with SeaBird Electronics SeaCat SBE19 or SBE 19Plus Conductivity, Temperature, and Depth (CTD) profilers. For ship acquisition, sound velocity profiles were acquired with the Brooke Ocean Moving Vessel Profiler MVP200. 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 SV profilers while the vessel is at rest.

C.6.1.2 Methods and Procedures

For both the individual SeaCat profilers and Rainier’s MVP-200, sound velocity profiles for CARIS were computed from raw pressure, temperature, and conductivity measurements using the program Velocipy. Velocipy was supplied to Rainier by the NOS Hydrographic Systems and Technology Programs N/CS11 (HSTP). Velocipy generated sound velocity profiles for CARIS in the .SVP format.

For survey launches, the speed of sound through the water was determined by a minimum of one cast for every four hours of SWMB acquisition. Casts were conducted more frequently when changing survey areas, or when it was felt that conditions, such as a change in weather, tide, or current, would warrant additional sound velocity profiles. Additionally, drastic changes in the surface sound velocity indicative of the need for a new cast were determined by observation of the real-time display of the Reson SVP 71 mounted on all Rainier SWMB launches.

While conducting survey operations with the ship and the MVP200, the frequency of casts were determined with the aid of the program “CastTime” developed at the University of New Hampshire’s Center for Coastal and Ocean Mapping / Joint Hydrographic Center. This tool monitors oceanographic variability in real-time based on sound speed data acquired by the MVP200. From this information, CastTime provides recommendations for optimal water-column sampling intervals. As a result, ship personnel are no longer required to subjectivity take casts based on some arbitrary time interval. Rather an improvement in sounding accuracy is realized with a sampling interval based on constant monitoring of oceanographic variability. In addition CastTime also prevent needless overworking of the underway profiler, saving on wear and tear maintenance costs for the MVP200 system.

When CastTime determines the need for a cast, the user is notified. After the first two casts are acquired at the configured initial sampling interval, the time of next cast is based purely on the real-time oceanographic variability and comparison to the previous cast. Each time a cast is acquired by the MVP and sent to CastTime, the data is sent automatically to SVP Editor where the profile can be viewed and edited. After any edits the cast is extended using climatological data from the World Ocean Atlas. This edited, extended cast is then sent directly to the SIS acquisition computer.

SIS also monitors changes in the surface sound speed vs. the value obtained with the last cast in real-time. The user is then warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

Processed MVP casts sent directly to the Kongsberg EM710 are applied to all subsequent SWMB data. This method has the drawback that the MVP cast taken prior to the collection of the SWMB data will always be applied rather than the SV cast that is geographically closest. This shortcoming may be circumvented by post applying SV data to all EM710 data in CARIS HIPS/SIPS.

All sound velocity profiles for CARIS, both CTD and MVP, are concatenated into a vessel-wide file in order of ascending time/date and saved in the appropriate vessel subdirectory of each sheet’s SVP folder. At the discretion of each individual sheet manager, a sheet-wide concatenated containing all sound velocity profiles may be generated and saved in the root of each sheet’s SVP folder. These concatenated file(s) are then applied to all HDCS data acquired, including that of the EM710, with the option “Nearest in distance within time (4 Hours)” selected under the “Profile Selection Method”.

On occasion, sound speed correction issues seen in the sounding data as characteristic “smiles” and “frowns” may force the Hydrographer to deviate from this standard. Refer to individual Descriptive Reports for further information regarding the application of sound velocity correctors specific to each survey.

C.6.2 Surface Sound Speed

C.6.2.1 Description of Correctors

All multibeam systems utilized on aboard Rainier require a sound velocity probe to be interfaced with the sonar acquisition unit for use in projector steering computations. During all survey operations, surface sound velocity probes are on at all times. In the event of a velocity probe failure, survey operations immediately cease until the failure is corrected.

C.6.2.2 Methods and Procedures

The Reson 7125-B SWMB systems utilized on vessels 2801 and 2803 require a sound velocity probe to be interfaced with the sonar acquisition unit for use in projector beam steering computations. A Reson SVP 71 surface sound velocity probe is utilized to feed real time sound speed values directly into the 7-P Sonar Processing Unit.

The Reson 7125 SV2 SWMB systems utilized on vessels 2802 and 2804 require a sound velocity probe to be interfaced with the sonar acquisition unit for use in projector beam steering computations. A Reson SVP 71 surface sound velocity probe is utilized to feed real time sound speed values directly into the 7-P Sonar Processing Unit.

The Kongsberg EM 710 multibeam systems utilized on aboard Rainier requires a sound velocity probe to be interfaced with the sonar acquisition unit for use in projector steering computations. A Reson SVP 70 surface sound velocity probe is utilized to feed real time SV values directly into the acquisition computer for use in beam steering calculations. Rainier’s MVP is also interfaced to send cast information directly to the SIS acquisition computer. SIS monitors changes in the surface sound speed vs. the value obtained with the last cast in real-time. The user is then warned for the need of a new cast by highlighting both the “SV Profile” and “SV Used” numerical displays in yellow with a difference greater than 3 m/s and red for a difference greater than 5 m/s.

D. APPROVAL

As Chief of Party, I have ensured that standard field surveying and processing procedures were followed during the 2016 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 (2016 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.

Approved and Forwarded: ______________________

Edward J. Van Den Ameele, CAPT/NOAA
Commanding Officer
NOAA Ship *Rainier*

In addition, the following individual was also responsible for overseeing data acquisition and processing of this project:

Chief Survey Technician: ______________________

James Jacobson
I am the author of this document
2016.09.25 17:45:42 -08'00'

James B. Jacobson
Chief Survey Technician
NOAA Ship *Rainier*

Field Operations Officer: ______________________

Digitally signed by Steven Loy
DN: cn=Steven Loy, o=NOAA, ou=NOAA RAINIER, email=ops.rainier@noaa.gov, c=US
Date: 2016.09.23 14:50:50 -08'00'

Steven Loy, LT/NOAA
Field Operations Officer
NOAA Ship *Rainier*