

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

## Data Acquisition & Processing Report

*Type of Survey* Hydrographic  
*Project No.* 2017 *Rainier* field season  
*Time frame* April - September 2017

### LOCALITY

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

2017

### CHIEF OF PARTY

Commander John J. Lomnický, NOAA  
Commander Benjamin K. Evans, NOAA

### LIBRARY & ARCHIVES

DATE

# Table of Contents

<u>A Equipment</u> .....	<u>1</u>
<u>A.1 Survey Vessels</u> .....	<u>1</u>
<u>A.1.1 NOAA Ship Rainier (WTEF)</u> .....	<u>1</u>
<u>A.1.2 RA3 (WZ2573)</u> .....	<u>5</u>
<u>A.1.3 RA4 (WZ2574)</u> .....	<u>9</u>
<u>A.1.4 RA5 (WZ2575)</u> .....	<u>13</u>
<u>A.1.5 RA6 (WZ2576)</u> .....	<u>18</u>
<u>A.1.6 RA7</u> .....	<u>22</u>
<u>A.1.7 RA8</u> .....	<u>23</u>
<u>A.2 Echo Sounding Equipment</u> .....	<u>25</u>
<u>A.2.1 Side Scan Sonars</u> .....	<u>25</u>
<u>A.2.2 Multibeam Echosounders</u> .....	<u>25</u>
<u>A.2.2.1 Kongsberg Model EM710</u> .....	<u>25</u>
<u>A.2.2.2 Reson SeaBat 7125-B</u> .....	<u>27</u>
<u>A.2.2.3 Reson Model SeaBat 7125 SV2</u> .....	<u>29</u>
<u>A.2.3 Single Beam Echosounders</u> .....	<u>32</u>
<u>A.2.4 Phase Measuring Bathymetric Sonars</u> .....	<u>32</u>
<u>A.2.5 Other Echosounders</u> .....	<u>32</u>
<u>A.3 Manual Sounding Equipment</u> .....	<u>33</u>
<u>A.3.1 Diver Depth Gauges</u> .....	<u>33</u>
<u>A.3.2 Lead Lines</u> .....	<u>33</u>
<u>A.3.3 Sounding Poles</u> .....	<u>33</u>
<u>A.3.4 Other Manual Sounding Equipment</u> .....	<u>33</u>
<u>A.4 Positioning and Attitude Equipment</u> .....	<u>33</u>
<u>A.4.1 Applanix POS/MV</u> .....	<u>33</u>
<u>A.4.2 DGPS</u> .....	<u>36</u>
<u>A.4.3 Trimble Backpacks</u> .....	<u>36</u>
<u>A.4.4 Laser Rangefinders</u> .....	<u>40</u>
<u>A.4.5 Other Positioning and Attitude Equipment</u> .....	<u>44</u>
<u>A.5 Sound Speed Equipment</u> .....	<u>44</u>
<u>A.5.1 Sound Speed Profiles</u> .....	<u>44</u>
<u>A.5.1.1 CTD Profilers</u> .....	<u>44</u>
<u>A.5.1.1.1 SEA-BIRD ELECTRONICS, INC. SBE 19 SEACAT</u> .....	<u>45</u>
<u>A.5.1.1.2 SEA-BIRD ELECTRONICS, INC. SBE 19plus SEACAT</u> .....	<u>47</u>
<u>A.5.1.2 Sound Speed Profilers</u> .....	<u>50</u>
<u>A.5.1.2.1 Rolls-Royce Group ODIM Brooke Ocean MVP200 Moving Vessel Profiler (MVP)</u> .....	<u>50</u>
<u>A.5.1.2.2 Lockheed Martin Sippican Inc., Sea-Air Systems Division XBT Deep Blue</u> .....	<u>51</u>
<u>A.5.2 Surface Sound Speed</u> .....	<u>53</u>

<u>A.5.2.1 Reson Inc. SVP 70</u> .....	<u>53</u>
<u>A.5.2.2 Reson Inc. SVP 71</u> .....	<u>54</u>
<u>A.6 Horizontal and Vertical Control Equipment</u> .....	<u>55</u>
<u>A.6.1 Horizontal Control Equipment</u> .....	<u>55</u>
<u>A.6.1.1 Base Station Equipment</u> .....	<u>56</u>
<u>A.6.1.2 Rover Equipment</u> .....	<u>61</u>
<u>A.6.2 Vertical Control Equipment</u> .....	<u>61</u>
<u>A.6.2.1 Water Level Gauges</u> .....	<u>61</u>
<u>A.6.2.2 Leveling Equipment</u> .....	<u>61</u>
<u>A.7 Computer Hardware and Software</u> .....	<u>62</u>
<u>A.7.1 Computer Hardware</u> .....	<u>62</u>
<u>A.7.2 Computer Software</u> .....	<u>63</u>
<u>A.8 Bottom Sampling Equipment</u> .....	<u>69</u>
<u>A.8.1 Bottom Samplers</u> .....	<u>69</u>
<u>A.8.1.1 Unknown Referred to as the “Nibbler”</u> .....	<u>69</u>
<u>A.8.1.2 AMS, Inc. 15 lb SST Dredge #445.10</u> .....	<u>70</u>
<u>A.8.1.3 Unknown Van Veen style grab sampler</u> .....	<u>72</u>
<u>B Quality Control</u> .....	<u>72</u>
<u>B.1 Data Acquisition</u> .....	<u>73</u>
<u>B.1.1 Bathymetry</u> .....	<u>73</u>
<u>B.1.2 Imagery</u> .....	<u>74</u>
<u>B.1.3 Sound Speed</u> .....	<u>74</u>
<u>B.1.4 Horizontal and Vertical Control</u> .....	<u>76</u>
<u>B.1.5 Feature Verification</u> .....	<u>78</u>
<u>B.1.6 Bottom Sampling</u> .....	<u>84</u>
<u>B.1.7 Backscatter</u> .....	<u>85</u>
<u>B.1.8 Other</u> .....	<u>85</u>
<u>B.2 Data Processing</u> .....	<u>85</u>
<u>B.2.1 Bathymetry</u> .....	<u>85</u>
<u>B.2.2 Imagery</u> .....	<u>89</u>
<u>B.2.3 Sound Speed</u> .....	<u>90</u>
<u>B.2.4 Horizontal and Vertical Control</u> .....	<u>91</u>
<u>B.2.5 Feature Verification</u> .....	<u>95</u>
<u>B.2.6 Backscatter</u> .....	<u>98</u>
<u>B.2.7 Other</u> .....	<u>99</u>
<u>B.3 Quality Management</u> .....	<u>100</u>
<u>B.4 Uncertainty and Error Management</u> .....	<u>102</u>
<u>B.4.1 Total Propagated Uncertainty (TPU)</u> .....	<u>104</u>
<u>B.4.2 Deviations</u> .....	<u>111</u>

<u>C Corrections To Echo Soundings .....</u>	<u>111</u>
<u>C.1 Vessel Offsets and Layback .....</u>	<u>111</u>
C.1.1 Vessel Offsets .....	111
C.1.2 Layback .....	117
<u>C.2 Static and Dynamic Draft .....</u>	<u>117</u>
C.2.1 Static Draft .....	117
C.2.2 Dynamic Draft .....	118
<u>C.3 System Alignment .....</u>	<u>121</u>
<u>C.4 Positioning and Attitude .....</u>	<u>126</u>
<u>C.5 Tides and Water Levels .....</u>	<u>128</u>
<u>C.6 Sound Speed .....</u>	<u>130</u>
C.6.1 Sound Speed Profiles .....	131
C.6.2 Surface Sound Speed .....	132

## **List of Figures**

<u>Figure 1: NOAA Ship Rainier (S221).....</u>	<u>4</u>
<u>Figure 2: Rainier survey launch RA3 (2803).....</u>	<u>9</u>
<u>Figure 3: Rainier survey launch RA4 (2801).....</u>	<u>13</u>
<u>Figure 4: Rainier survey launch RA5 (2802).....</u>	<u>17</u>
<u>Figure 5: Rainier survey launch RA6 (2804).....</u>	<u>21</u>
<u>Figure 6: Rainier survey skiff RA7 (1907).....</u>	<u>23</u>
<u>Figure 7: Rainier survey skiff RA8 (1905).....</u>	<u>24</u>
<u>Figure 8: Kongsberg EM710 sonar transducer housing on Rainier (S221).....</u>	<u>27</u>
<u>Figure 9: Reson SeaBat 7125-B mounted on survey launch 2801.....</u>	<u>29</u>
<u>Figure 10: Reson SeaBat 7125 SV2 mounted on survey launch 2804.....</u>	<u>32</u>
<u>Figure 11: A Toughbook laptop computer Field5 in use on a skiff collecting shoreline data.....</u>	<u>39</u>
<u>Figure 12: The Leica DISTO lite5 being used to measure the waterline of a survey launch.....</u>	<u>41</u>
<u>Figure 13: Image of VLP-16 LiDAR sensor mounted on survey launch 2804.....</u>	<u>44</u>
<u>Figure 17: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.....</u>	<u>54</u>
<u>Figure 18: A SVP 71 mounted just aft of a Reson multibeam transducer on a survey launch.....</u>	<u>55</u>
<u>Figure 19: 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.....</u>	<u>61</u>
<u>Figure 20: The "Nibbler", a foot-trip clam shell style bottom sampler.....</u>	<u>70</u>
<u>Figure 21: The AMS 15 lb SST Dredge #445.10 Ponar type grab sampler.....</u>	<u>71</u>
<u>Figure 22: The Van Veen grab sampler configured ready to deploy.....</u>	<u>72</u>
<u>Figure 23: A Rainier base station installed on Fox Island near Cold Bay, Alaska.....</u>	<u>78</u>
<u>Figure 24: Survey skiff RA7 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.....</u>	<u>83</u>

[Figure 25: The magenta track-line collected in the field with a skiff and CARIS Notebook used to position a new rock.....](#) [84](#)

[Figure 26: Depth range vs. CUBE surface resolution.....](#) [88](#)

[Figure 27: The historic dynamic draft graph showing the Rainier altered values \(light blue\) against the historic values \(dark blue\).....](#) [119](#)

## Data Acquisition and Processing Report

### NOAA Ship Rainier

Chief of Party: CDR John J. Lomnicky, NOAA & CDR Benjamin K. Evans, NOAA

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## A Equipment

### A.1 Survey Vessels

#### A.1.1 NOAA Ship Rainier (WTEF)

<i>Name</i>	NOAA Ship Rainier (WTEF)	
<i>Hull Number</i>	S221	
<i>Description</i>	Steel hydrographic ship	
<i>Utilization</i>	Mid-water multibeam, towed side scanning sonar	
<i>Dimensions</i>	<i>LOA</i>	70.4 meters
	<i>Beam</i>	12.8 meters
	<i>Max Draft</i>	4.7 meters
<i>Most Recent Full Static Survey</i>	<i>Date</i>	2014-04-20
	<i>Performed By</i>	The IMTEC Group, Ltd.
	<i>Discussion</i>	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 antennas, and multiple ship reference points were all determined.

<i>Most Recent Partial Static Survey</i>	<i>Date</i>	2015-04-20
	<i>Performed By</i>	NOAA Ship Rainier personel
	<i>Discussion</i>	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 "2017 SSS Layback S221" report attached to this document. The relative position of the towpoint was then used to generate corresponding HVF.
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	
<i>Most Recent Partial Offset Verification</i>	<i>Date</i>	2016-04-19
	<i>Method Used</i>	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	<i>Discussion</i>	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.

<i>Most Recent Static Draft Determination</i>	<i>Date</i>	2014-04-20
	<i>Method Used</i>	Survey personnel record direct measurements to waterline from port and starboard benchmarks.
	<i>Discussion</i>	<p>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.</p>

<i>Most Recent Dynamic Draft Determination</i>	<i>Date</i>	2013-05-01
	<i>Method Used</i>	The ellipsoidally referenced method
	<i>Discussion</i>	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. See section C.2.2 of this report for more information regarding the determination of S221's dynamic draft corrector.



*Figure 1: NOAA Ship Rainier (S221)*

**A.1.2 RA3 (WZ2573)**

<i>Name</i>	RA3 (WZ2573)	
<i>Hull Number</i>	2803	
<i>Description</i>	Aluminum hull Jensen survey launch	
<i>Utilization</i>	Shallow water multibeam, hull mounted side scanning sonar	
<i>Dimensions</i>	<i>LOA</i>	8.8 meters
	<i>Beam</i>	3.7 meters
	<i>Max Draft</i>	1.1 meters
<i>Most Recent Full Static Survey</i>	<i>Date</i>	2009-03-01
	<i>Performed By</i>	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
	<i>Discussion</i>	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.
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	

<i>Most Recent Partial Offset Verification</i>	<i>Date</i>	2017-03-30
	<i>Method Used</i>	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	<i>Discussion</i>	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2017 Sonar Offset Measurements” and “2017 Sonar Offsets” reports attached to this document. During the 2016-17 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 “2017 GPS Offsets” and “2017 GPS Offsets Measurements” reports attached to this document.

<i>Most Recent Static Draft Determination</i>	<i>Date</i>	2017-03-31
	<i>Method Used</i>	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	<i>Discussion</i>	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 differed from the corresponding NGS benchmark to produce a waterline value. These six values were averaged together to produce a final value. Draft uncertainty is determined based on the standard deviation of these six values. Values measured and derived may be found in the “2017 Waterline measurements” and “2017 Waterline” reports attached to this document.

<i>Most Recent Dynamic Draft Determination</i>	<i>Date</i>	2015-03-09
	<i>Method Used</i>	Dynamic draft determined using historical values.
	<i>Discussion</i>	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 2017 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)**

<i>Name</i>	RA4 (WZ2574)	
<i>Hull Number</i>	2801	
<i>Description</i>	Aluminum hull Jensen survey launch	
<i>Utilization</i>	Shallow water multibeam, hull mounted side scanning sonar	
<i>Dimensions</i>	<i>LOA</i>	8.8 meters
	<i>Beam</i>	3.7 meters
	<i>Max Draft</i>	1.1 meters

<i>Most Recent Full Static Survey</i>	<i>Date</i>	2008-03-31
	<i>Performed By</i>	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
	<i>Discussion</i>	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.
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	

<i>Most Recent Partial Offset Verification</i>	<i>Date</i>	2017-03-30
	<i>Method Used</i>	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	<i>Discussion</i>	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2017 Sonar Offset Measurements” and “2017 Sonar Offsets” reports attached to this document. During the 2016-17 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 “2017 GPS Offsets” and “2017 GPS Offsets Measurements” reports attached to this document.

<i>Most Recent Static Draft Determination</i>	<i>Date</i>	2017-03-30
	<i>Method Used</i>	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	<i>Discussion</i>	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 differed from the corresponding NGS benchmark to produce a waterline value. These six values were averaged together to produce a final value. Draft uncertainty is determined based on the standard deviation of these six values. Values measured and derived may be found in the “2017 Waterline measurements” and “2017 Waterline” reports attached to this document.

<i>Most Recent Dynamic Draft Determination</i>	<i>Date</i>	2015-03-09
	<i>Method Used</i>	Dynamic draft determined using historical values.
	<i>Discussion</i>	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 2017 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)**

<i>Name</i>	RA5 (WZ2575)
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<i>Hull Number</i>	2802	
<i>Description</i>	Aluminum hull Jensen survey launch	
<i>Utilization</i>	Shallow water multibeam, hull mounted side scanning sonar, side scanning laser	
<i>Dimensions</i>	<i>LOA</i>	8.8 meters
	<i>Beam</i>	3.7 meters
	<i>Max Draft</i>	1.1 meters
<i>Most Recent Full Static Survey</i>	<i>Date</i>	2008-03-31
	<i>Performed By</i>	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
	<i>Discussion</i>	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.
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	

<i>Most Recent Partial Offset Verification</i>	<i>Date</i>	2017-03-21
	<i>Method Used</i>	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	<i>Discussion</i>	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2017 Sonar Offset Measurements” and “2017 Sonar Offsets” reports attached to this document. During the 2016-17 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 “2017 GPS Offsets” and “2017 GPS Offsets Measurements” reports attached to this document.

<i>Most Recent Static Draft Determination</i>	<i>Date</i>	2017-03-20
	<i>Method Used</i>	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	<i>Discussion</i>	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 differed from the corresponding NGS benchmark to produce a waterline value. These six values were averaged together to produce a final value. Draft uncertainty is determined based on the standard deviation of these six values. Values measured and derived may be found in the “2017 Waterline measurements” and “2017 Waterline” reports attached to this document.

<i>Most Recent Dynamic Draft Determination</i>	<i>Date</i>	2015-03-09
	<i>Method Used</i>	Dynamic draft determined using historical values.
	<i>Discussion</i>	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 2017 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)**

<i>Name</i>	RA6 (WZ2576)	
<i>Hull Number</i>	2804	
<i>Description</i>	Aluminum hull Jensen survey launch	
<i>Utilization</i>	Shallow water multibeam, hull mounted side scanning sonar, side scanning laser	
<i>Dimensions</i>	<i>LOA</i>	8.8 meters
	<i>Beam</i>	3.7 meters
	<i>Max Draft</i>	1.1 meters
<i>Most Recent Full Static Survey</i>	<i>Date</i>	2009-03-01
	<i>Performed By</i>	National Geodetic Survey, Geodetic Services Division Instrumentation & Methodologies Branch
	<i>Discussion</i>	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.
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	

<i>Most Recent Partial Offset Verification</i>	<i>Date</i>	2017-03-21
	<i>Method Used</i>	Verification measurements were conducted using steel tapes, steel rulers, laser range finders, carpenter levels, optical levels, plum-bobs, and carpenter squares.
	<i>Discussion</i>	During the 2016-17 winter repair period survey personnel measured the position of the sonar transducers relative to a forward keel benchmark. The positions of this benchmark and others on the launch were established by initial NGS full static survey. Roll and pitch values of the launch were also simultaneously measured using the POS/MV. By plugging these surveyed measurements into a counter pitch/roll matrix, the coordinates of the sonar transducers were derived. Values measured and derived may be found in the “2017 Sonar Offset Measurements” and “2017 Sonar Offsets” reports attached to this document. During the 2016-17 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 “2017 GPS Offsets” and “2017 GPS Offsets Measurements” reports attached to this document.

<i>Most Recent Static Draft Determination</i>	<i>Date</i>	2017-03-20
	<i>Method Used</i>	Static draft determined by direct measurement of the distance between launch benchmarks and the waterline while the launch was in the water.
	<i>Discussion</i>	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 differed from the corresponding NGS benchmark to produce a waterline value. These six values were averaged together to produce a final value. Draft uncertainty is determined based on the standard deviation of these six values. Values measured and derived may be found in the “2017 Waterline measurements” and “2017 Waterline” reports attached to this document.

<i>Most Recent Dynamic Draft Determination</i>	<i>Date</i>	2015-03-09
	<i>Method Used</i>	Dynamic draft determined using historical values.
	<i>Discussion</i>	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 2017 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**

<i>Name</i>	RA7	
<i>Hull Number</i>	1907	
<i>Description</i>	Aluminum hull SeaArk survey skiff	
<i>Utilization</i>	Shoreline verification	
<i>Dimensions</i>	<i>LOA</i>	5.7 meters
	<i>Beam</i>	2.8 meters
	<i>Max Draft</i>	0.35 meters
<i>Most Recent Full Static Survey</i>	Full static survey was not performed.	
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	
<i>Most Recent Partial Offset Verification</i>	Partial offset verification was not performed.	
<i>Most Recent Static Draft Determination</i>	Static draft determination was not performed.	
<i>Most Recent Dynamic Draft Determination</i>	Dynamic draft determination was not performed.	



*Figure 6: Rainier survey skiff RA7 (1907)*

### **A.1.7 RA8**

<i>Name</i>	RA8
<i>Hull Number</i>	1905
<i>Description</i>	Aluminum hull SeaArk survey skiff
<i>Utilization</i>	Shoreline verification

<i>Dimensions</i>	<i>LOA</i>	5.7 meters
	<i>Beam</i>	2.8 meters
	<i>Max Draft</i>	0.35 meters
<i>Most Recent Full Static Survey</i>	Full static survey was not performed.	
<i>Most Recent Partial Static Survey</i>	Partial static survey was not performed.	
<i>Most Recent Full Offset Verification</i>	Full offset verification was not performed.	
<i>Most Recent Partial Offset Verification</i>	Partial offset verification was not performed.	
<i>Most Recent Static Draft Determination</i>	Static draft determination was not performed.	
<i>Most Recent Dynamic Draft Determination</i>	Dynamic draft determination was not performed.	



*Figure 7: Rainier survey skiff RA8 (1905)*

## A.2 Echo Sounding Equipment

### A.2.1 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

### A.2.2 Multibeam Echosounders

#### A.2.2.1 Kongsberg Model EM710

<i>Manufacturer</i>	Kongsberg
<i>Model</i>	Model EM710
<i>Description</i>	<p>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 <math>\frac{1}{2}^\circ</math> with a receive beam width of <math>1^\circ</math>. 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 beamspace may be set to be either equiangular or equidistant. Rainier typically collects 400 beams per ping in equidistant mode.</p> <p>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.</p>

<i>Serial Numbers</i>	<i>Vessel Installed On</i>	S221		
	<i>Processor s/n</i>	0356		
	<i>Transceiver s/n</i>	unknown		
	<i>Transducer s/n</i>	unknown		
	<i>Receiver s/n</i>	218		
	<i>Projector 1 s/n</i>	unknown		
	<i>Projector 2 s/n</i>	n/a		
<i>Specifications</i>	<i>Frequency</i>	100 kilohertz		
	<i>Beamwidth</i>	<i>Along Track</i>	0.5 degrees	
		<i>Across Track</i>	1.0 degrees	
	<i>Max Ping Rate</i>	30 hertz		
	<i>Beam Spacing</i>	<i>Beam Spacing Mode</i>	Equidistant	
		<i>Number of Beams</i>	400	
	<i>Max Swath Width</i>	140 degrees		
	<i>Depth Resolution</i>	1 centimeters		
<i>Depth Rating</i>	<i>Manufacturer Specified</i>	2000 meters		
	<i>Ship Usage</i>	400 meters		
<i>Manufacturer Calibrations</i>	Manufacturer calibration was not performed.			
<i>System Accuracy Tests</i>	<i>Vessel Installed On</i>	S221		
	<i>Methods</i>	<p>Due to both logistic issues and the relatively tight turns that would be required, Rainier did not acquire EM710 data on the Chiniak Bay reference surface near Kodiak as did all the launches. In lieu of this surface comparison, an area was found where 2801 Reson 7125 high frequency crosslines were acquired over main scheme EM710 ship data. Select sections of two crosslines were used for the comparison. CUBE Reference surfaces with a 4-meter resolution were created for both the 2801 Reson 7125 high frequency crosslines and EM710 main scheme ship data. Both surfaces were referenced to MLLW. Because no "true value" of the reference surface exists, the 2801 Reson 7125 high frequency reference surface was considered as the "zero" datum for the comparison. While conducting a the pre-fieldseason patch test for the ship in the Straits of Juan de Fuca, the ship also ran a reference surface consisting of a grid of 4 x 4 lines in ~150 meters of water. While no launch data was collected in the same area for comparison, a check of internal consistency was done by comparing a surface generated using the 4 north-south lines against a surface generated using the 4 east-west lines. These two surfaces compared well, with a mean difference of 0.05 meters.</p>		
	<i>Results</i>	See attached "2017 Reference Surface Comparison" report.		

<i>Snippets</i>	Sonar does not have snippets logging capability.
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*Figure 8: Kongsberg EM710 sonar transducer housing on Rainier (S221).*

#### **A.2.2.2 Reson SeaBat 7125-B**

<i>Manufacturer</i>	Reson
<i>Model</i>	SeaBat 7125-B
<i>Description</i>	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.

	<p>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 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.</p> <p>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.</p>				
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	2801 (RA-4)	2803 (RA-3)	spare	
	<i>Processor s/n</i>	4408002	2708007	4707073	
	<i>Transceiver s/n</i>	1515002	1515033	1515007	
	<i>Transducer s/n</i>	n/a	n/a	n/a	
	<i>Receiver s/n</i>	5006315	808052	2208058	
	<i>Projector 1 s/n</i>	608560	608558	2808016	
	<i>Projector 2 s/n</i>	1908188	908167	1908193	
<i>Specifications</i>	<i>Frequency</i>	200 kilohertz		400 kilohertz	
	<i>Beamwidth</i>	<i>Along Track</i>	2.0 degrees	<i>Along Track</i>	1.0 degrees
		<i>Across Track</i>	1.0 degrees	<i>Across Track</i>	0.5 degrees
	<i>Max Ping Rate</i>	50 hertz		50 hertz	
	<i>Beam Spacing</i>	<i>Beam Spacing Mode</i>	Equidistant	<i>Beam Spacing Mode</i>	Equidistant
		<i>Number of Beams</i>	256	<i>Number of Beams</i>	512
	<i>Max Swath Width</i>	128 degrees		128 degrees	
	<i>Depth Resolution</i>	5 millimeters		5 millimeters	
<i>Depth Rating</i>	<i>Manufacturer Specified</i>	500 meters	<i>Manufacturer Specified</i>	200 meters	
	<i>Ship Usage</i>	200 meters	<i>Ship Usage</i>	50 meters	
<i>Manufacturer Calibrations</i>	Manufacturer calibration was not performed.				

<i>System Accuracy Tests</i>	<i>Vessel Installed On</i>	2801 and 2803
	<i>Methods</i>	The reference surface used for launch-to-launch sonar system comparisons is located in Chiniak Bay near Kodiak, Alaska. The surface is a roughly 340m square made up of a grid of five lines by five lines. The reference surface gently slopes up to the northeast from a depth of 40 meters to a depth of 25 meters. 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. CUBE Reference surfaces with a 1-meter resolution were created for each system and frequency. All surfaces were referenced to MLLW. Because no "true value" of the reference surface exists, the 2801 Reson 7125 high frequency reference surface was considered as the "zero" datum for all comparisons.
	<i>Results</i>	See attached "2017 Reference Surface Comparison" report.
<i>Snippets</i>	Sonar has snippets logging capability.	



*Figure 9: Reson SeaBat 7125-B mounted on survey launch 2801.*

### **A.2.2.3 Reson Model SeaBat 7125 SV2**

<i>Manufacturer</i>	Reson		
<i>Model</i>	Model SeaBat 7125 SV2		
<i>Description</i>	<p>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 &amp; 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.</p> <p>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.</p> <p>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.</p> <p>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.</p>		
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	2802 (RA-5)	2804 (RA-6)
	<i>Processor s/n</i>	18343513086	18343413083
	<i>Transceiver s/n</i>	n/a	n/a
	<i>Transducer s/n</i>	n/a	n/a
	<i>Receiver s/n</i>	1513556	1513564
	<i>Projector 1 s/n</i>	2413037	4912146
	<i>Projector 2 s/n</i>	None	None

<i>Specifications</i>	<i>Frequency</i>	200 kilohertz		400 kilohertz	
	<i>Beamwidth</i>	<i>Along Track</i>	2.0 degrees	<i>Along Track</i>	1.0 degrees
		<i>Across Track</i>	1.0 degrees	<i>Across Track</i>	0.5 degrees
	<i>Max Ping Rate</i>	50 hertz		50 hertz	
	<i>Beam Spacing</i>	<i>Beam Spacing Mode</i>	Equidistant	<i>Beam Spacing Mode</i>	Equidistant
		<i>Number of Beams</i>	256	<i>Number of Beams</i>	512
	<i>Max Swath Width</i>	140 degrees		140 degrees	
	<i>Depth Resolution</i>	6 millimeters		6 millimeters	
<i>Depth Rating</i>	<i>Manufacturer Specified</i>	450 meters	<i>Manufacturer Specified</i>	175 meters	
	<i>Ship Usage</i>	200 kilometers	<i>Ship Usage</i>	50 meters	
<i>Manufacturer Calibrations</i>	Manufacturer calibration was not performed.				
<i>System Accuracy Tests</i>	<i>Vessel Installed On</i>	2802 and 2804			
	<i>Methods</i>	The reference surface used for launch-to-launch sonar system comparisons is located in Chiniak Bay near Kodiak, Alaska. The surface is a roughly 340m square made up of a grid of five lines by five lines. The reference surface gently slopes up to the northeast from a depth of 40 meters to a depth of 25 meters. 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. CUBE Reference surfaces with a 1-meter resolution were created for each system and frequency. All surfaces were referenced to MLLW. Because no "true value" of the reference surface exists, the 2801 Reson 7125 high frequency reference surface was considered as the "zero" datum for all comparisons.			
	<i>Results</i>	See attached "2017 Reference Surface Comparison" report.			
<i>Snippets</i>	Sonar has snippets logging capability.				



*Figure 10: Reson SeaBat 7125 SV2 mounted on survey launch 2804.*

### **A.2.3 Single Beam Echosounders**

No single beam echosounders were utilized for data acquisition.

### **A.2.4 Phase Measuring Bathymetric Sonars**

No phase measuring bathymetric sonars were utilized for data acquisition.

### **A.2.5 Other Echosounders**

No additional echosounders were utilized for data acquisition.

### **A.3 Manual Sounding Equipment**

#### **A.3.1 Diver Depth Gauges**

No diver depth gauges were utilized for data acquisition.

#### **A.3.2 Lead Lines**

No lead lines were utilized for data acquisition.

#### **A.3.3 Sounding Poles**

No sounding poles were utilized for data acquisition.

#### **A.3.4 Other Manual Sounding Equipment**

No additional manual sounding equipment was utilized for data acquisition.

#### **Additional Discussion**

### **A.4 Positioning and Attitude Equipment**

#### **A.4.1 Applanix POS/MV**

<i>Manufacturer</i>	Applanix
<i>Model</i>	POS MV V5
<i>Description</i>	<p>Rainier and all of her launches are outfitted with the Applanix POS/MV 320 version 5. The POS MV version 5 offers a number of key new features including:</p> <ul style="list-style-type: none"> <li>• Full GNSS support, by using all available GPS and GLONASS satellites.</li> <li>• Improved Real Time Kinematic (RTK) performance over long baselines using the most advanced Trimble algorithms.</li> <li>• Removable USB media slot, providing convenient, portable and robust logging of</li> </ul>

### 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  $0.02^\circ$  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  $0.05^\circ$  are observed. Heading accuracy is monitored by the launch crew and survey operations are temporarily suspended in the event that the error exceeds  $0.08^\circ$ .

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  $0.008^\circ$  and heading data with an accuracy of  $0.02^\circ$ . 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.						
<i>PCS</i>	<i>Manufacturer</i>	Applanix					
	<i>Model</i>	POS/MV 320 V5					
	<i>Description</i>	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.					
	<i>Firmware Version</i>	9.13					
	<i>Software Version</i>	9.12					
	<i>Serial Numbers</i>	<i>Vessel Installed On</i>	S221	2801 (RA4)	2802 (RA5)	2803 (RA3)	2804 (RA6)
	<i>PCS s/n</i>	7273	7264	7162	7272	7274	
<i>IMU</i>	<i>Manufacturer</i>	Applanix					
	<i>Model</i>	LN200					
	<i>Description</i>	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.					
	<i>Serial Numbers</i>	<i>Vessel Installed On</i>	S221	2801 (RA4)	2802 (RA5)	2803 (RA3)	2804 (RA6)
		<i>IMU s/n</i>	353	693	694	334	355
	<i>Certification</i>	IMU certification report was not produced.					
<i>Antennas</i>	<i>Manufacturer</i>	Trimble					
	<i>Model</i>	Aero Antenna Technology Inc (re-branded as Trimble)					
	<i>Description</i>	Used by S221					

<i>Serial Numbers</i>	<i>Vessel Installed On</i>	<i>Antenna s/n</i>	<i>Port or Starboard</i>	<i>Primary or Secondary</i>		
	S221	8197	Port	Primary		
	S221	8188	Starboard	Secondary		
<i>Manufacturer</i>	Trimble					
<i>Model</i>	Aero Antenna Technology Inc (re-branded as Trimble)					
<i>Description</i>	Used by 2801 & 2802					
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	<i>Antenna s/n</i>	<i>Port or Starboard</i>	<i>Primary or Secondary</i>		
	2801	8196	Port	Primary		
	2801	8186	Starboard	Secondary		
	2802	8184	Port	Primary		
	2802	8182	Starboard	Secondary		
<i>Manufacturer</i>	Trimble					
<i>Model</i>	Aero Antenna Technology Inc (re-branded as Trimble) AT1675-540TS					
<i>Description</i>	Used by 2803 & 2804					
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	<i>Antenna s/n</i>	<i>Port or Starboard</i>	<i>Primary or Secondary</i>		
	2803	8187	Port	Primary		
	2803	8181	Starboard	Secondary		
	2804	8978	Port	Primary		
	2804	8979	Starboard	Secondary		
<i>GAMS Calibration</i>	<i>Vessel</i>	2801	2802	2803	2804	S221
	<i>Calibration Date</i>	2017-03-04	2017-03-22	2017-04-20	2017-03-22	2017-04-13
<i>Configuration Reports</i>	<i>Vessel</i>	2801	2802	2803	2804	S221
	<i>Report Date</i>	2017-03-04	2017-03-22	2017-04-20	2017-03-22	2017-04-13

### A.4.2 DGPS

DGPS equipment was not utilized for data acquisition.

### A.4.3 Trimble Backpacks

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

<i>Field Computers</i>	<i>Manufacturer</i>	Panasonic
	<i>Model</i>	Toughbook CF-30
	<i>Description</i>	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.
	<i>Operating System</i>	Windows XP
	<i>Serial Numbers</i>	8HKSB80775 (Field2)
		8HKSB80724 (Field 4)
	<i>Manufacturer</i>	Panasonic
	<i>Model</i>	Toughbook CF-31
	<i>Description</i>	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.
	<i>Operating System</i>	Windows 7 (x64)
	<i>Serial Numbers</i>	3ITSB60204 (Field5)
		3ITSB60201 (Field6)
<i>Manufacturer</i>	Panasonic	
<i>Model</i>	Toughbook CF-54	
<i>Description</i>	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.	
<i>Operating System</i>	Windows 7 Professional (32-bit)	
<i>Serial Numbers</i>	5ITSA19236 (Field 1)	
	5ITSA19168 (Field3)	

<i>DQA Tests</i>	<i>Date</i>	2017-02-01
	<i>Serial Number</i>	0224070094 & 0224070154
	<i>Methods</i>	During a two day period (February 1-2 2017), 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.
	<i>Results</i>	The largest difference seen between the published position of the benchmark and Trimble backpack positions produced during DQA testing was 0.553 meters in differential and 1.280 meters in non-differential.



*Figure 11: A Toughbook laptop computer Field5 in use on a skiff collecting shoreline data.*

#### A.4.4 Laser Rangefinders

<i>Manufacturer</i>	Laser Technology Inc.
<i>Model</i>	Impulse 200 LR
<i>Description</i>	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.
<i>Serial Numbers</i>	108786
<i>DQA Tests</i>	DQA test was not performed.

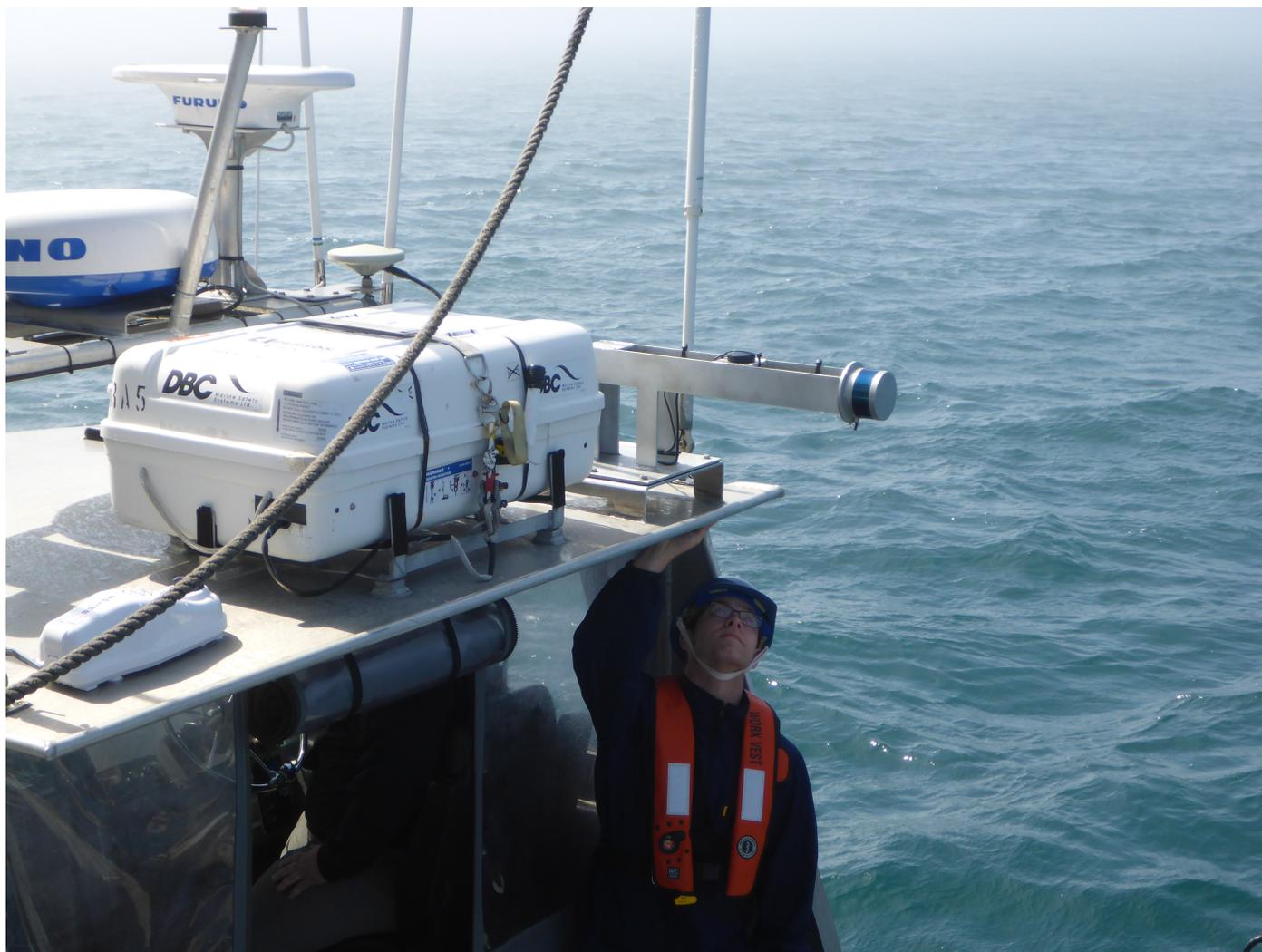
<i>Manufacturer</i>	Leica
<i>Model</i>	DISTO lite5
<i>Description</i>	The Leica DISTO lite5 is a splash and dust proof handheld laser rangefinder that emits a Class II 0.95mW laser on a wavelength of 620-690nm. Ranges measurable vary from 0.2m up to 200m with the smallest unit displayed 1mm. Measuring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



*Figure 12: The Leica DISTO lite5 being used to measure the waterline of a survey launch.*

<i>Manufacturer</i>	Velodyne			
<i>Model</i>	VLP-16			
<i>Description</i>	<p>The VLP-16 is a real-time 3D LiDAR (Light Detection And Ranging) sensor that provides high definition 3-dimensional information about the surrounding environment. The VLP-16 creates 360° 3D images by using 16 laser/detector pairs mounted in a compact housing. The housing rapidly spins to scan the surrounding environment. The lasers fire thousands of times per second, providing a rich, 3D point cloud in real time.</p> <p>Advanced digital signal processing and waveform analysis provide high accuracy, extended distance sensing, and calibrated reflectivity data. Unique features include: Horizontal Field of View (FOV) of 360°, Rotational speed of 5-20 rotations per second (adjustable), Vertical Field of View (FOV) of 30°, Returns of up to 100 meters (useful range depends on application). Accuracy of ~3cm is typical.</p> <p>VLP-16 units are integrated into launch Hypack acquisition systems and are used for positioning of shoreline features.</p>			
<i>Serial Numbers</i>	<table border="1"> <tr> <td>29114353 on RA 5</td> </tr> <tr> <td>29414281 on RA 6</td> </tr> <tr> <td>29415368 spare</td> </tr> </table>	29114353 on RA 5	29414281 on RA 6	29415368 spare
29114353 on RA 5				
29414281 on RA 6				
29415368 spare				

<i>DQA Tests</i>	<i>Date</i>	2017-04-04
	<i>Serial Number</i>	29114353 on RA 5
	<i>Methods</i>	Laser Patch Test
	<i>Results</i>	The laser patch test plan consisted of two parallel lines ~25 meters apart using a navigational aid pile as a target. Lidar data was collected in both directions on these two lines for a total of four calibration lines. The patch test was then processed using HYSWEEP® SURVEY and MBMAX64 (64-bit HYSWEEP® EDITOR) in the order find the Roll, Pitch and then Yaw mounting bias values. The resulting patch test values were then stored to the HYSWEEP® HARDWARE configuration to be logged in the HSX files. These values are valid for as long as the LiDAR sensor mounting stays the same.
	<i>Date</i>	2017-04-04
	<i>Serial Number</i>	29414281 on RA 6
	<i>Methods</i>	Laser Patch Test
	<i>Results</i>	The laser patch test plan consisted of two parallel lines ~25 meters apart using a navigational aid pile as a target. LiDAR data was collected in both directions on these two lines for a total of four calibration lines. The patch test was then processed using HYSWEEP® SURVEY and MBMAX64 (64-bit HYSWEEP® EDITOR) in the order find the Roll, Pitch and then Yaw mounting bias values. The resulting patch test values were then stored to the HYSWEEP® HARDWARE configuration to be logged in the HSX files. These values are valid for as long as the LiDAR sensor mounting stays the same.



*Figure 13: Image of VLP-16 LiDAR sensor mounted on survey launch 2804.*

#### **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**

<i>Manufacturer</i>	SEA-BIRD ELECTRONICS, INC.	
<i>Model</i>	SBE 19 SEACAT	
<i>Description</i>	<p>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.</p> <p>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.</p> <p>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.</p>	
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	n/a
	<i>CTD s/n</i>	192472 -0281 (green)
<i>Calibrations</i>	<i>CTD s/n</i>	192472-0281
	<i>Date</i>	2017-01-31
	<i>Procedures</i>	The CTD profiler is returned to Sea-Bird electronics Inc. in Bellevue Washington for yearly post cruise calibration.



*Figure 14: 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**

<i>Manufacturer</i>	SEA-BIRD ELECTRONICS, INC.					
<i>Model</i>	SBE 19plus SEACAT					
<i>Description</i>	<p>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.</p> <p>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”.</p> <p>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.</p> <p>One SBE 19plus SEACAT profiler, 19P-7530 (red), was inadvertently not returned to Sea-Bird for its yearly calibration. Using the 2016 calibration values, profiler 19P-7530 passed regular DQC checks with the other profilers throughout the 2017 field season. In light of these positive results, profiler 19P-7530 was used throughout the 2017 field season using 2016 calibration values.</p>					
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	n/a	n/a	n/a	n/a	n/a
	<i>CTD s/n</i>	19P 26069-4039 (black)	19P 27151-4114 (yellow)	19P 30319-4306 (blue)	19P 31464-4343 (purple)	19P-7530 (red)

<i>Calibrations</i>	<i>CTD s/n</i>	26069-4039	27151-4114	30319-4306	31464-4343	7530
	<i>Date</i>	2017-01-13	2017-01-13	2017-01-13	2017-01-14	2016-01-19
	<i>Procedures</i>	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 was inadvertently not returned to Sea-Bird electronics Inc. in Bellevue Washington for 2017 field season. Calibration values from the 2016 field season were used.



*Figure 15: 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)

<i>Manufacturer</i>	Rolls-Royce Group ODIM Brooke Ocean													
<i>Model</i>	MVP200 Moving Vessel Profiler (MVP)													
<i>Description</i>	<p>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.</p> <p>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.</p> <p>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.</p>													
<i>Serial Numbers</i>	<table border="1"> <tr> <td><i>Vessel Installed On</i></td> <td>S221 Rainier</td> <td>spare</td> <td>spare</td> <td>spare</td> </tr> <tr> <td><i>Sound Speed Profiler s/n</i></td> <td>7510</td> <td>8614</td> <td>7761</td> <td>7511</td> </tr> </table>				<i>Vessel Installed On</i>	S221 Rainier	spare	spare	spare	<i>Sound Speed Profiler s/n</i>	7510	8614	7761	7511
<i>Vessel Installed On</i>	S221 Rainier	spare	spare	spare										
<i>Sound Speed Profiler s/n</i>	7510	8614	7761	7511										

<i>Calibrations</i>	<i>Sound Speed Profiler s/n</i>	7761	8614	7510	7511
	<i>Date</i>	2016-04-11	2016-04-11	2016-04-11	2016-04-15
	<i>Procedures</i>	In consultation with the vendor it was determined that Applied Microsystems Micro CTDs require calibration only every other year if the unit maintained in storage and sees no field use. A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	In consultation with the vendor it was determined that Applied Microsystems Micro CTDs require calibration only every other year if the unit maintained in storage and sees no field use. A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	In consultation with the vendor it was determined that Applied Microsystems Micro CTDs require calibration only every other year if the unit maintained in storage and sees no field use. A manufacturer calibration consists of sending the instrument to AML Oceanographic in Sidney B.C. Canada for individual temperature, pressure, and conductivity calibrations.	In consultation with the vendor it was determined that Applied Microsystems Micro CTDs require calibration only every other year if the unit maintained in storage and sees no field use. 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

<i>Manufacturer</i>	Lockheed Martin Sippican Inc., Sea-Air Systems Division
<i>Model</i>	XBT Deep Blue
<i>Description</i>	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  $\pm 0.1^{\circ}\text{C}$ .

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  $\pm 2\%$  and a vertical resolution of 65cm. When the probe reaches its maximum depth (a function of ship speed and the quantity of wire contained within the shipboard spool) the profile is completed and the system is ready for another launch.

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

The operator uses the computer to select the type of probe to be launched along with other parameters to be stored such as date, time and latitude/longitude (by manual input or NMEA string). The computer performs system diagnostics and prelaunch tests and then indicates the probe is ready for launch. The computer then receives probe data during the descent and displays and stores the information. The XBT data is easily translated to an ASCII text format (.edf file) that Velocipy can process into CARIS SVP format files.

<i>Serial Numbers</i>	<i>Vessel Installed On</i>	LMA3 XBT Launcher (Rainier)	MK21 Oceanographic Data Acquisition System (Rainier)
	<i>Sound Speed Profiler s/n</i>	162402	10250
<i>Calibrations</i>	No CTD profiler calibrations were performed.		



Figure 16: 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

<i>Manufacturer</i>	Reson Inc.
<i>Model</i>	SVP 70
<i>Description</i>	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.		
<i>Serial Numbers</i>	<i>Vessel Installed On</i>	S221	S221
	<i>Sound Speed Sensor s/n</i>	301302	4408373
<i>Calibrations</i>	No CTD profiler calibrations were performed.		



*Figure 17: Dual SVP 70s mounted in Rainier's multibeam sonar transducer gondola.*

#### **A.5.2.2 Reson Inc. SVP 71**

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



*Figure 18: 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

<p><i>Description</i></p>	<p>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.</p> <p>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.</p> <p>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.</p>			
<p><i>GPS Antennas</i></p>	<p><i>Manufacturer</i></p>	<p>Trimble Navigation Ltd.</p>		
	<p><i>Model</i></p>	<p>Zephyr Geodetic 2</p>		
	<p><i>Description</i></p>	<p>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.</p>		
	<p><i>Serial Numbers</i></p>	<table border="1"> <tr> <td data-bbox="699 1425 1503 1482">30767941</td> </tr> <tr> <td data-bbox="699 1482 1503 1539">1441031030</td> </tr> </table>	30767941	1441031030
30767941				
1441031030				

<i>GPS Receivers</i>	<i>Manufacturer</i>	Trimble Navigation Limited
	<i>Model</i>	NetR5
	<i>Description</i>	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.
	<i>Firmware Version</i>	unknown
	<i>Serial Numbers</i>	4910K61066 (Moe)
	<i>Manufacturer</i>	Trimble Navigation Limited
	<i>Model</i>	NetR9
	<i>Description</i>	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.
	<i>Firmware Version</i>	unknown
	<i>Serial Numbers</i>	5034K69715 (Curly) 5429R49194 (Larry)

<i>UHF Antennas</i>	<i>Manufacturer</i>	L-com Global Connectivity
	<i>Model</i>	HGV-906U 800/900 MHz 6 dBi Omnidirectional Antenna
	<i>Description</i>	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.
	<i>Serial Numbers</i>	n/a
	<i>Manufacturer</i>	PCTEL Inc.
	<i>Model</i>	Bluewave BGYD890M
	<i>Description</i>	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.
	<i>Serial Numbers</i>	n/a

<i>UHF Radios</i>	<i>Manufacturer</i>	Freewave
	<i>Model</i>	HTP-900RE
	<i>Description</i>	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.
	<i>Firmware Version</i>	n/a
	<i>Serial Numbers</i>	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		
<i>Solar Panels</i>	<i>Manufacturer</i>	Uni-Solar (United Solar Systems Corp)
	<i>Model</i>	MBC-525
	<i>Description</i>	The Uni-Solar MBC-525 is a flexible 51" X 16" solar panel rated at 22 watts.
	<i>Serial Numbers</i>	n/a

<i>Solar Chargers</i>	<i>Manufacturer</i>	Morning Star
	<i>Model</i>	Sun Saver 10 SS-10L-12V
	<i>Description</i>	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.
	<i>Serial Numbers</i>	n/a
<i>DQA Tests</i>	No DQA tests were performed.	



*Figure 19: 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**

<i>Manufacturer</i>	Carl Zeiss											
<i>Model</i>	Zeiss Ni2											
<i>Description</i>	<p>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.</p> <p>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.</p>											
<i>Serial Numbers</i>	<table border="1"> <tr><td>87102</td></tr> <tr><td>67312</td></tr> <tr><td>100518</td></tr> </table>			87102	67312	100518						
87102												
67312												
100518												
<i>Calibrations</i>	<table border="1"> <tr> <td><i>Level s/n</i></td> <td>67312 and 87102</td> <td>100518</td> </tr> <tr> <td><i>Date</i></td> <td>2017-02-16</td> <td>2017-04-04</td> </tr> <tr> <td><i>Procedures</i></td> <td>The levels were returned to Kuker-Ranken Inc. for annual cleaning, inspection, adjustment, and calibration.</td> <td>The levels were returned to Kuker-Ranken Inc. for annual cleaning, inspection, adjustment, and calibration. This level required additional work to rebuild its compensator.</td> </tr> </table>	<i>Level s/n</i>	67312 and 87102	100518	<i>Date</i>	2017-02-16	2017-04-04	<i>Procedures</i>	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 to rebuild its compensator.		
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<i>Date</i>	2017-02-16	2017-04-04										
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<i>Kukkamaki</i>	<table border="1"> <tr> <td><i>Level s/n</i></td> <td>67312 and 87102</td> <td>100518</td> </tr> <tr> <td><i>Date</i></td> <td>2017-03-31</td> <td>2017-03-31</td> </tr> <tr> <td><i>Procedures</i></td> <td>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.</td> <td>UPDATE THIS DATE/SECTION, THIS LEVEL STILL NEEDS A KUKKAMAKI RUN 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.</td> </tr> </table>	<i>Level s/n</i>	67312 and 87102	100518	<i>Date</i>	2017-03-31	2017-03-31	<i>Procedures</i>	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.	UPDATE THIS DATE/SECTION, THIS LEVEL STILL NEEDS A KUKKAMAKI RUN 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.		
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**A.7 Computer Hardware and Software**

### A.7.1 Computer Hardware

No computer hardware was utilized for data acquisition.

### A.7.2 Computer Software

<i>Manufacturer</i>	CARIS
<i>Software Name</i>	HIPS and SIPS (x64)
<i>Version</i>	9.1
<i>Service Pack</i>	N/A
<i>Hotfix</i>	7
<i>Installation Date</i>	2017-02-23
<i>Use</i>	Processing
<i>Description</i>	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.

<i>Manufacturer</i>	CARIS
<i>Software Name</i>	HIPS and SIPS (x64)
<i>Version</i>	10.2
<i>Service Pack</i>	N/A
<i>Hotfix</i>	3
<i>Installation Date</i>	2017-06-06
<i>Use</i>	Processing
<i>Description</i>	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.

<i>Manufacturer</i>	CARIS
<i>Software Name</i>	HIPS and SIPS (x64)
<i>Version</i>	10.3
<i>Service Pack</i>	N/A
<i>Hotfix</i>	3
<i>Installation Date</i>	2017-09-16
<i>Use</i>	Processing

<i>Description</i>	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.
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<i>Manufacturer</i>	CARIS
<i>Software Name</i>	BASE Editor (x64)
<i>Version</i>	4.2
<i>Service Pack</i>	n/a
<i>Hotfix</i>	16
<i>Installation Date</i>	2017-04-01
<i>Use</i>	Processing
<i>Description</i>	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.

<i>Manufacturer</i>	CARIS
<i>Software Name</i>	Notebook
<i>Version</i>	3.1.1
<i>Service Pack</i>	1
<i>Hotfix</i>	2
<i>Installation Date</i>	2017-02-23
<i>Use</i>	Acquisition and Processing
<i>Description</i>	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.

<i>Manufacturer</i>	Applanix
<i>Software Name</i>	POSPac MMS
<i>Version</i>	7.1.5812.24143

<i>Service Pack</i>	1
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2016-05-25
<i>Use</i>	Processing
<i>Description</i>	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.

<i>Manufacturer</i>	Applanix
<i>Software Name</i>	POSPac MMS
<i>Version</i>	8.1.6388.30062
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-12-01
<i>Use</i>	Processing
<i>Description</i>	In addition to all of the features found in the previous version, POSPac Mobile Mapping Suite now includes Trimble CenterPoint RTX trajectory processing. This Post Processed Real Time Extended (PP-RTX) next generation software allows direct geo-referencing of mobile mapping sensors using GNSS and inertial technology. PP-RTX is able to achieve centimeter-level accuracy within one hour after data collection with just an internet connection, there no need to wait for delivery of public-domain ephemeris data. Another advantage of PP-RRTX is the ability to chart in remote regions that have no existing Continuously Operation Reference Stations (CORS) without the need to deploying local base stations. PP-RTX achieves this through a global deployment of highly redundant monitoring stations that are connected through the internet and are used to determine the precise satellite data with maximum accuracy, robustness, continuity and reliability, along with advance algorithms and receiver and antenna calibrations.

<i>Manufacturer</i>	Fledermaus
<i>Software Name</i>	FM Geocoder Toolbox
<i>Version</i>	7.7.7
<i>Service Pack</i>	build 674

<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-03-01
<i>Use</i>	Processing
<i>Description</i>	Fledermaus Geocoder Toolbox (FMGT) is designed to visualize and analyze backscatter data from MBES sensors. The software can read multiple files of backscatter data, apply corrections, and then create a 2D representation of the ocean floor called a backscatter mosaic. Once the mosaic has been generated, various statistics can be calculated and exported in a number of formats, along with the mosaic backscatter value.

<i>Manufacturer</i>	NOAA (HSTP)
<i>Software Name</i>	Pydro 64
<i>Version</i>	16.9 R6932
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-02-23
<i>Use</i>	Processing
<i>Description</i>	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)

<i>Manufacturer</i>	NOAA (HSTP)
<i>Software Name</i>	Pydro XL
<i>Version</i>	17.05b
<i>Service Pack</i>	N/A
<i>Hotfix</i>	N/A
<i>Installation Date</i>	2017-05-23
<i>Use</i>	Processing
<i>Description</i>	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)

<i>Manufacturer</i>	HYPACK, Inc.
<i>Software Name</i>	Hypack 2017
<i>Version</i>	17.0.34.0

<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2016-04-19
<i>Use</i>	Acquisition
<i>Description</i>	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.

<i>Manufacturer</i>	Kongsberg Maritime AS
<i>Software Name</i>	SIS
<i>Version</i>	4.2.1
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2016-01-11
<i>Use</i>	Acquisition
<i>Description</i>	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.

<i>Manufacturer</i>	Applanix Corporation
<i>Software Name</i>	MV-POSView
<i>Version</i>	9.03
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-03-14
<i>Use</i>	Acquisition
<i>Description</i>	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.

<i>Manufacturer</i>	ODIM
<i>Software Name</i>	MVP Controller

<i>Version</i>	2.430
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2015-07-16
<i>Use</i>	Acquisition
<i>Description</i>	MVP Controller

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

<i>Manufacturer</i>	NOAA (HSTP)
<i>Software Name</i>	Velocipy
<i>Version</i>	v17.11(r7485)
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-06-14
<i>Use</i>	Acquisition and Processing
<i>Description</i>	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.

<i>Manufacturer</i>	NOAA (HSTP)
<i>Software Name</i>	SSP Manager
<i>Version</i>	2.2.10
<i>Service Pack</i>	n/a

<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-04-02
<i>Use</i>	Acquisition and Processing
<i>Description</i>	SSP Manager processes XBT/SVP/CTD data for being used by acoustic systems. This software eventually grew into Sound Speed Manager (SSM).

<i>Manufacturer</i>	NOAA (HSTP)
<i>Software Name</i>	Sound Speed Manager
<i>Version</i>	v.2017.6.20
<i>Service Pack</i>	n/a
<i>Hotfix</i>	n/a
<i>Installation Date</i>	2017-06-20
<i>Use</i>	Acquisition and Processing
<i>Description</i>	Sound Speed Manager (SSM) aims to merge together functionality of NOAA Velocity to download process sound speed profiles (SSP) for underwater acoustic systems with the ability to export these processed files in any required format. The main functionalities of SSM include: wide support of commonly-used sound speed profile formats, full integration with common data acquisition/integration applications (e.g., Kongsberg SIS), profile enhancement based on real-time and climatologic models, and database management of the collected data with built-in functionalities for analysis and visualization.

## A.8 Bottom Sampling Equipment

### A.8.1 Bottom Samplers

#### A.8.1.1 Unknown Referred to as the “Nibbler”

<i>Manufacturer</i>	Unknown
<i>Model</i>	Referred to as the “Nibbler”
<i>Description</i>	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.



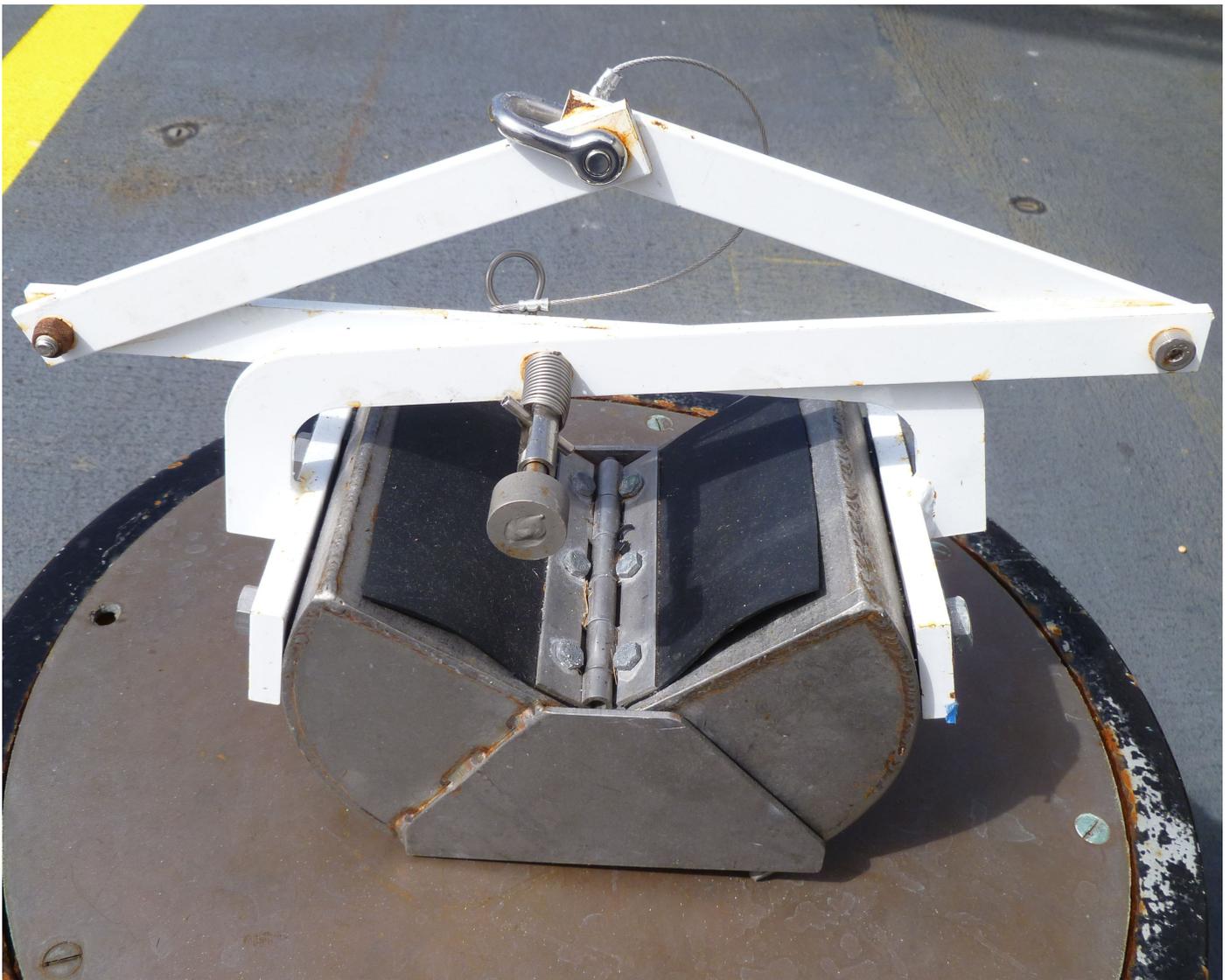
Figure 20: The “Nibbler”, a foot-trip clam shell style bottom sampler.

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

<i>Manufacturer</i>	AMS, Inc.
<i>Model</i>	15 lb SST Dredge #445.10
<i>Description</i>	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 21: The AMS 15 lb SST Dredge #445.10 Ponar type grab sampler.*

### A.8.1.3 Unknown Van Veen style grab sampler

<i>Manufacturer</i>	Unknown
<i>Model</i>	Van Veen style grab sampler
<i>Description</i>	<p>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.</p> <p>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.</p>



*Figure 22: 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**

Side scan sonar imagery was not acquired.

### **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 Olympic Coast project which contains charted depths in excess of 400 fathoms (~730m), Rainier was provided with the XBT probes and launcher that include enough wire to cast a maximum depth of 760m. This depth exceeds the maximum depth of casts possible from the ship with her current winch setup. XBTs have the additional advantage of being deployable while the ship is underway. Casts from this system are created and downloaded in Sippican/Lockheed software and then processed in Velocipy and Sound Speed Manager.

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

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

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

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

Real Time Position and Attitude Acquisition:

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

The POS/MV .000 files are collected individually by each launch daily, beginning at least five minutes before the collection of bathymetric data and ending at least five minutes after the conclusion of bathymetric

data collection. Logging is started by opening the MV-POSView window and selecting “Ethernet Realtime...” from the Logging menu. In the Ethernet Realtime Output Control window only the following message groups are selected: 3, 7, 20, 102, 111 and 113. The Output Control rate is also set to ‘50 Hz’. It is also important not log through UTC Midnight on Saturdays, the end of the GPS week. In the event that a line would cross over UTC Midnight, Hypack/Hysweep logging and POS file logging is stopped and a new POS file with a new day number is started after UTC midnight.

#### 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 23: A Rainier base station installed on Fox Island near Cold 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 1/2" 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 `asgmt=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 “asnmt” 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 disproof 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 disproof 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.

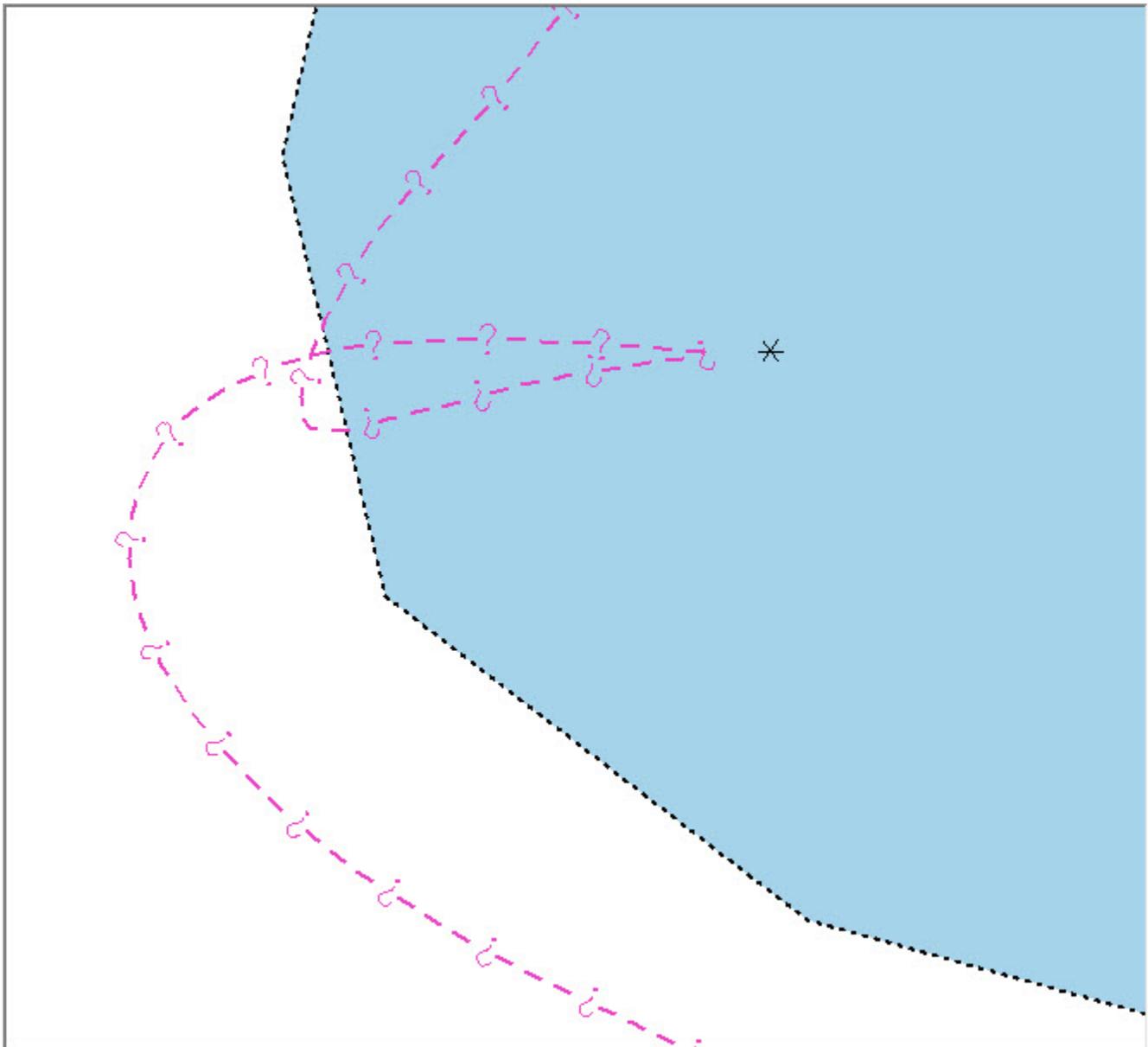
New to the Rainier for the 2017 field season is feature acquisition using the launch based Velodyne LiDAR system. The laser is mounted above and behind the cox'n on the starboard side of the launch and oriented in such a way as to optimize data collection in a athwart ship ribbon favoring the starboard side of the launch. To collect data the launch is driven at a speed no faster than 6 knots, slower for small or far away features. When possible the laser head should be kept 30-60 meters from the feature of interest. Sunny days are not preferred, overcast weather is the best.

As the launch drive past features, a real time point cloud is created in Hypack. The amount of points able to be displayed depends on the amount of RAM in the acquisition computer. The user is able to manipulate views of this point cloud as data is collected, enabling the attribute features that have been scanned in near real time. The target button lets the user select the highest sounding on the feature which may then be attributed with the correct feature type and other any other pertinent information. The appropriate S57 code for the feature is selected from the S57 Code drop-down menu (such as "Pile"). Currently there is no underwater/ rock awash selection. For the interim, these features are marked as obstructions and corrected in later processing.

Although the Velodyne system excels at positioning and finding the heights of well exposed features it is not without issues. Any low-lying features, particularly near-awash rocks or reefs surrounded by kelp are nearly impossible to distinguish in the point cloud. Any submerged features will also be missed with this system.



*Figure 24: Survey skiff RA7 collecting the along-shore buffer line using a Trimble GPS backpack system connected to an external battery and a Toughbook computer.*



*Figure 25: 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. Snippet data contains the amplitude data of each individual sonar beam in a swath.

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 >  $\pm\text{SQRT}(a^2+(b*d)^2)$  , 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.

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

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

- Naming convention is Hxxxxx\_4m\_DNxxx.
- The surface is created as a single resolution CUBE surface at 4m resolution.
- The CUBE surface is colored using a standardized custom Rainier generated CARIS Colour Range table.
- The color palette selected is intended to aid swift navigation over previously surveyed areas in addition to highlighting shallow areas.

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

<b>Depth Range Filtering</b>	<b>CUBE Surface Resolution</b>	<b>BASE surface Advanced Options Configuration</b>
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 26: 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**

<i>Methods Used</i>	Surface Computation Algorithms
<i>Description</i>	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).

New to the 2017 field season is the Trimble CenterPoint RTX positioning solution which combines the methodology of PPP with advanced ambiguity resolution technology to produce cm level accuracies without the need for local reference stations.

Smart Base:

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

Applanix POSPac software is used to produce a Smoothed Best Estimate of Trajectory (SBET) file. The SBET file consists of GPS position and attitude data corrected and integrated with inertial measurements and reference station correctors, exported into WGS84. The SBET is created using the Applanix proprietary “SmartBase” algorithm, which generates a Virtual Reference Station (VRS) on site from a network of established reference stations surrounding the project area, generally the Continually Operating Reference Station (CORS) network. Reference station data is downloaded with the POSPac MMS download tool and usually available within 24 hours. These SBET navigation and attitude files are applied to all lines in

CARIS and supersede initial positioning and attitude data. For further details on the CORS network stations utilized in addition to processing methodology, refer to the HVCR of the appropriate project.

#### Single Base:

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

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

#### Precise Point Positioning:

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

#### PP-RTX

PP-RTX is used when CORS stations are unavailable and a shore-side reference station would be difficult or impossible to install due to topography, distance from shore, or land use restrictions. Smoothed Best Estimate of Trajectory (SBET) files and associated Root Mean Square (RMS) files are calculated using the Applanix Position and Orientation System Post-processing Package Mobile Mapping Suite (POSPac MMS) version 8.1.6 software. All SBET/RMS files are created in POSPac MMS 8.1 using the "Post Processed Real Time Extended" (PP-RTX) aided-inertial processing mode that uses both terrestrial based reference station data combined with wide-area coverage GNSS satellite corrections to generate precise orbit, clock, and observation biases for satellites on a global scale. These corrections are accessed by POSPac MMS 8.1 via internet access to a Trimble network to provide centimeter level positioning corrections which are then applied by RTX to ship and survey launch POS files. No locally installed GPS base stations or CORS station data are used to generate PP-RTX mode SBET/RMS files.

#### Methodology:

POSPac .000 and base station data processing conforms to the Ellipsoidally Referenced Surveys Standard Operating Procedure document in the Appendix IV of the FPM . By post processing the POSPac .000, GNSS and base station data, POSPac creates SBET (smoothed best estimate trajectory) files which are used by CARIS along with the corresponding POSPac .000 file to improve the data collected. Applying SBETs in

CARIS HIPS increase the accuracies of attitude and navigation related data. Currently it is the responsibility of the HorCon project manager and the sheet manager to work together applying SBETs to the survey after post acquisition tasks are complete.

The favored method of processing raw POS MV data from launches requires input from nearby semi-permanent shore stations. POSpac has two options for handling shore stations, Single Baseline and SmartBase processing. SmartBase processing is the preferred method but Rainier must often install their own base station and use the single base station method due to the dearth of CORS stations in Alaska. For the single base station method, the primary-reference baseline separation must be less than 20 km at the start and end of the mission and can occasionally grow to 100 km during the mission. For the SmartBase method, an optimal network consists of six to eight reference stations evenly distributed around the surveyed area and separated by 50 to 70 km. A minimum of four stations are required for Applanix SmartBase processing.

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Initial base station processing requires:

- Processing RAW GPS base station data – When geographically possible, raw GPS data is downloaded daily from shore stations as (.T01/.T02) files. These files are converted into RINEX format using Trimble utility program “Convert to RINEX – TBC utility” v2.1.1.0. Three files are produced, files .YYg, .YYn, and .YYo.
- Obtaining Base Station OPUS Solution -- After creating RINEX files from the base station receiver raw file, the .YYo file is then submitted to OPUS in order to get a precise position solution. If bandwidth is an issue, as it usually is aboard the ship, the RINEX file may need to be decimated and zipped to get the file size smaller and achieve a reasonable upload time. A 3mb file usually takes about 3-5 minutes to upload on the ship’s Vsat.
- OPUS reference frame and format -- Once the RINEX file size is reasonable (under 7mb), go to the OPUS website at: <http://www.ngs.noaa.gov/OPUS>. At the OPUS site the user is given the option to choose the new IGS08 reference from or the old ITRF00 reference frame. Until further testing and verification is done, Rainier continues to use the old ITRF00 reference frame. For Solution Formats, the extended solution + XML (DRAFT) is selected. Once processed, a NGS OPUS solution report is produced in .txt format. It is in this report that the WGS84 coordinates of the base station which are later entered into POSpac are found.
- Single Base Station Processing
  - 1) Open Applanix POSpac™ Mobile Mapping Suite and set up the project
  - 2) Load the Applanix .000 file (recorded on the launch)

- 3) Load the satellite data logged by the base station (the .YYo file that corresponds to the day number being processed).
  - 4) Once the coordinate manager window opens, the true ITRF coordinates from the OPUS report is input. The same ITRF coordinates are used throughout the project and are checked against "new" OPUS solutions to maintain consistency.
  - 5) Both the SBET (in ITRF format) and smrmsg error data files are created.
- Smart Base Processing
    - 1) Open Applanix POSPac™ Mobile Mapping Suite and set up the project
    - 2) Load the Applanix .000 file (recorded on the launch)
    - 3) Select the "Find Base Stations" option which will generate a list of nearby CORS stations and then click on the "Smart Select" button.
    - 4) POSPac will need the Internet to access and download the base station data it finds as the best option to import. It will need a minimum of 4 stations as well as adequate ephemeris data to continue. This process is done automatically.
    - 5) Once the base stations and ephemeris data have been downloaded, the Raw Data Check-In window will appear automatically, click OK. Once you click OK, POSPac will create a triangulated network of all the base stations it has chosen for processing.
    - 6) Next run the SmartBase Quality Check. POSPac will run the quality check to see if the data downloaded is good enough for processing and generate a Results Summary. If the data is inferior, it will recommend to Re-run the SmartBase Quality Check processor or that there is not enough adequate data to continue.
    - 7) Due to the remote locations Rainier surveys, sometimes there is not an optimal amount of data available. Occasionally you have to override the system and see if the SBET generated is up to spec. This is done by running the Applanix SmartBase processor.
    - 8) Once the Applanix SmartBase processor has finished, the outline of the triangulated network will be highlighted in yellow. This means that you are ready for processing and that the appropriate base stations have been designated and set.
  - Batch Processing -- Batch processing allows processing of multiple POS/MV .000 files from multiple vessels on a once per day per survey sheet basis.
  - POSPac SBET Quality Control -- Once the POSPac project has completed processing successfully, quality control of the SBETs (Smoothed Best Estimated Trajectories) is performed.
  - Exporting Custom SBET -- Once the QC is complete and the processing log updated, the next step

is to export a custom SBET in NAD83.

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

- 1) Process --> Load Attitude/Navigation data... Load the WGS84 SBET files. Import data for Navigation, Gyro, Pitch, Roll, and GPS Height are all selected for survey launches. Only Navigation and GPS Height are selected for the ship.
- 2) Process --> Load Error data... Load the smrmsg error data file. Import data for Position RMS, Roll RMS, Pitch RMS, and Gyro RMS are selected for survey launches. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values. Only Position RMS is selected for the ship.

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 as 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 2017 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 files are then placed in the appropriate locations in the working projects directory.

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

the .csv file, and input waterline offset measurements to create a new S57 file with correct the heights to account for the location of the IMU relative to the waterline. In Caris this new S57 file can be exported as a .hob file to be tide corrected using Caris Notebook.

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

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

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

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

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

- "Good" seafloor is not rejected anywhere. Any bad soundings are cleaned out to make the surface represent the seafloor, but there is no cut-off of soundings shoaler than the 4-meter or 0-meter curves. Negative soundings are fine so long as they accurately represent the bottom.
- No launch is to go inside the NALL line trying for the 0-meter curve, or developing items that are found outside the survey limits (i.e. NALL line)
- For cultural features (pilings, piers, buoy's and buoy chains, etc.) that are above MLLW (i.e. negative sounding) AND on the CSF HOB layer, all soundings on the cultural item are deleted. This technique will prevent the BASE surface from being pulled up on features already charted above MLLW in the HOB file.
- For cultural features that are below MLLW, the shoalest sounding is designated (which the BASE surface will honor) AND the feature is included on the field verified HOB file.

- For cultural features that are above MLLW and are not on the field verified HOB file, the least depth is flagged as "outstanding," but not included in the BASE surface and all other data on the object is rejected. In this case, the "outstanding" sounding is used as a basis for creating a new feature in the field verified HOB, but it will not affect the BASE surface. This is accomplished by using the option in BASE surface creation to not include outstanding soundings. Alternatively, in the case of area-type cultural features, all depths may be temporarily retained and the resultant DTM used to digitize the feature. Once digitization is complete, all soundings on the cultural item are deleted.
- Rocks and reefs are treated as "seafloor." No data is rejected on rocks, reefs or ledges, even above MLLW. The primary method of getting heights on rocks will remain "leveling" (aka eyeballing) during traditional shoreline, but if a least depth of a rock is obtained with MBES, it will be designated and the height/depth will be used as the VALSOU in the CSF HOB. As previously stated, launches will not go inshore of the NALL line trying to get these data, but it will not be discarded if they are obtained. In cases where the echosounder data does not get the least depth, the soundings obtained will be left in the surface and a DP (or previously acquired comp source data) will be used for the feature.

Following acquisition, digital photos are renamed with an unique ID and moved into the "Multimedia" folder. Any required application of tide and SV corrections are performed in CARIS Notebook.

#### S-57 Attribution

With the advent of custom CARIS support files supplied by OCS, CARIS Notebook, Bathy DataBase, and Plot Composer now supports feature flags previously available only in Pydro. All feature flagging can now be accomplished in CARIS Notebook while Pydro used for generating reports and performing QC.

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

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

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

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

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

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

- descrip - 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".
- descrip - 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".
- descrip - 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".
- descrip - 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.
- descrip – 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**

For the North Kodiak project no formal processing of backscatter data were performed. Backscatter data were converted per the 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.

Although Rainier began the field season with no requirement to process and submit backscatter this changed with Hydrographic Surveys Technical Directive 2017-4 (Processed Backscatter) which required full backscatter processing starting with the Cold Bay project. Beginning with this project, Rainier processed and submitted backscatter mosaics as part of the regular data submission package.

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

- A new project is created for each sheet and each vessel and each sonar frequency. Thus one sheet can have multiple projects, one (or more) for each launch and possibly one more for the Rainier.
- Vessel parameters are set. Vessel parameters allow the hydrographer to set configurations for each launch, frequency, and pulse length, in order calibrate slight differences in decibel levels. This results in a smoother, less patchwork appearance of backscatter mosaics between each launch and frequency/pulse length. Parameter values may be determined by running a calibration line in the same direction with each possible combination of vessel, frequency, and pulse length.
- Lines are imported into FMGT. One mosaic is created per boat and frequency. So, if one boat had worked both 200kHz and 400kHz, 2 mosaics are created; one for each frequency.
- Create a mosaic. Any crosslines not needed in the mosaic are deselected. The backscatter mosaics should be kept under 200 MB to keep the program from crashing. Set the export type as grayscale GeoTIFF.

## 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.

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

Charlene is an automated night processing and data transfer tool developed by NOAA's Office of Coast Survey in early 2017. Night processing includes all of those tasks in between raw data collection and a final daily product that occur each night on our hydrographic vessels. Charlene allows the user to:

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

## 6. Use NOAA tools like AutoQC, QCTools and TCARI

Charlene is a HSTB developed software utility that automates hydrographic ‘night processing’. Night processing includes all of those tasks in between raw data collection and a final daily product that occur each night on our hydrographic vessels. Our goal with Charlene is to make night processing something that requires little to no user interaction.

The development of Charlene was made possible when recent versions of Caris and Applanix (10.2 and 8.1 respectively) opened up machine access to the processes in these packages. This now allowed the ability to run these software packages outside of the graphical interface. Charlene leverages this to become a one-stop shop for night processing. The key to all this is that Charlene works across software platforms; it can transfer raw data to the appropriate submission folders, process SBETs, convert survey lines into Caris, apply sound velocity profiles, water levels, and SBETs, run in-house QC reports, and generate logs. In practice, Rainier has set up Charlene to largely follow the current processing pipeline with the exception of now adopting the official file submission structure for data storage instead of creating it just for the data submission.

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”.

New to the 2017 field season, Variable Resolution BASE surfaces have been approved as the final deliverable. VR surfaces come in two flavors, depth based and density based. Depth based VR surfaces roughly follow the same depth band resolutions as the single resolutions surfaces followed in the past. On

the other hand density based VR surface resolution is instead determined based on the resolution that can be supported due to sounding density. With most modern high density sounding systems, this will usually push the finer resolution to deeper than historic values.

To meet the required sounding density and holiday detection parameters, Rainier adheres to the estimation method parameter values recommended in Hydrographic Surveys Technical Directive 2017-2 (Variable Resolution Bathymetric Grids). Results are double check using QC tools 2 now include as part of Pydro.

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

<Survey registry number>\_<Sounding Type>\_VR\_<Vertical Datum>

(EX: “H12345\_MB\_VR\_MLLW” is the variable resolution surface of survey H12345 referenced to MLLW) or

(EX: “H12345\_MB\_VR\_MLLW\_Final” is the finalized variable resolution surface of survey H12345 referenced to MLLW)

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. In cases where XBT casts are used on a sheet, the recommended value of 4.0 m/s is used.

- Surface sound speed value is dependent on the manufacturer specifications of the unit utilized to measure surface SV values for refraction corrections to flat-faced transducers. The Reson SVP 71 fixed-mount sound velocity probe is affixed to launches 2801 2802, 2803 and 2804 to provide correctors for the flat 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.

### ERZT SEP Uncertainty Calculation

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

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

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

The Mean of Standard Deviation is found by:

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

The Total Linear Nautical Miles is found by:

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

The Total 1km Nodes is found by:

- Select all of the nodes in your 1000 m separation model.
- Get the total number of nodes from the bottom of the screen.

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

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

In addition to the usual a priori estimates of uncertainty, some real-time and post-processed uncertainty sources were also incorporated into the depth estimates of Rainier surveys. Real-time uncertainties from the Reson 7125 and Kongsberg EM710 were recorded and applied in post-processing. Applanix TrueHeave files are recorded on all survey vessels, which include an estimate of the heave uncertainty, and are applied during post-processing. Finally, the post-processed uncertainties associated with vessel roll, pitch, gyro and navigation are applied in CARIS HIPS via an SBET RMS file generated in POSPac.

## **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 “2017 HVF summary” included with this report.

**B.4.1.3 TPU Values**

<i>Vessel</i>	2801_Reson7125_HF_512		
<i>Echosounder</i>	Reson SeaBat 7125-B 400 kilohertz		
<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
	<i>Navigation Position</i>	1.000 meters	
	<i>Timing</i>	<i>Transducer</i>	0.005 seconds
		<i>Navigation</i>	0.005 seconds
		<i>Gyro</i>	0.005 seconds
		<i>Heave</i>	0.005 seconds
		<i>Pitch</i>	0.005 seconds
		<i>Roll</i>	0.005 seconds
	<i>Offsets</i>	<i>x</i>	0.010 meters
		<i>y</i>	0.010 meters
		<i>z</i>	0.010 meters
	<i>MRU Alignment</i>	<i>Gyro</i>	0.147 degrees
		<i>Pitch</i>	0.099 degrees
		<i>Roll</i>	0.099 degrees
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second
		<i>Loading</i>	0.019 meters
<i>Draft</i>		0.005 meters	
<i>Delta Draft</i>		0.010 meters	
<i>Vessel</i>	2801_Reson7125_LF_256		
<i>Echosounder</i>	Reson SeaBat 7125-B 200 kilohertz		
<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
<i>Navigation Position</i>	1.000 meters		

	<i>Timing</i>	<i>Transducer</i>	0.005 seconds
		<i>Navigation</i>	0.005 seconds
		<i>Gyro</i>	0.005 seconds
		<i>Heave</i>	0.005 seconds
		<i>Pitch</i>	0.005 seconds
		<i>Roll</i>	0.005 seconds
	<i>Offsets</i>	<i>x</i>	0.010 meters
		<i>y</i>	0.010 meters
		<i>z</i>	0.010 meters
	<i>MRU Alignment</i>	<i>Gyro</i>	0.107 degrees
		<i>Pitch</i>	0.083 degrees
		<i>Roll</i>	0.083 degrees
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second
		<i>Loading</i>	0.019 meters
		<i>Draft</i>	0.005 meters
		<i>Delta Draft</i>	0.010 meters
<i>Vessel</i>	2802_Reson7125_HF_512		
<i>Echosounder</i>	Reson SeaBat 7125 SV2 400 kilohertz		
<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
	<i>Navigation Position</i>	1.000 meters	
	<i>Timing</i>	<i>Transducer</i>	0.005 seconds
		<i>Navigation</i>	0.005 seconds
		<i>Gyro</i>	0.005 seconds
		<i>Heave</i>	0.005 seconds
<i>Pitch</i>		0.005 seconds	
<i>Roll</i>		0.005 seconds	
<i>Offsets</i>	<i>x</i>	0.010 meters	
	<i>y</i>	0.010 meters	
	<i>z</i>	0.010 meters	

	<table border="1"> <tbody> <tr> <td rowspan="3"><i>MRU Alignment</i></td> <td><i>Gyro</i></td> <td>0.157 degrees</td> </tr> <tr> <td><i>Pitch</i></td> <td>0.106 degrees</td> </tr> <tr> <td><i>Roll</i></td> <td>0.106 degrees</td> </tr> <tr> <td rowspan="4"><i>Vessel</i></td> <td><i>Speed</i></td> <td>0.080 meters/second</td> </tr> <tr> <td><i>Loading</i></td> <td>0.019 meters</td> </tr> <tr> <td><i>Draft</i></td> <td>0.010 meters</td> </tr> <tr> <td><i>Delta Draft</i></td> <td>0.010 meters</td> </tr> </tbody> </table>	<i>MRU Alignment</i>	<i>Gyro</i>	0.157 degrees	<i>Pitch</i>	0.106 degrees	<i>Roll</i>	0.106 degrees	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second	<i>Loading</i>	0.019 meters	<i>Draft</i>	0.010 meters	<i>Delta Draft</i>	0.010 meters																																
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<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
	<i>Navigation Position</i>	1.000 meters	
	<i>Timing</i>	<i>Transducer</i>	0.005 seconds
		<i>Navigation</i>	0.005 seconds
		<i>Gyro</i>	0.005 seconds
		<i>Heave</i>	0.005 seconds
		<i>Pitch</i>	0.005 seconds
		<i>Roll</i>	0.005 seconds
	<i>Offsets</i>	<i>x</i>	0.010 meters
		<i>y</i>	0.010 meters
		<i>z</i>	0.010 meters
	<i>MRU Alignment</i>	<i>Gyro</i>	0.060 degrees
		<i>Pitch</i>	0.064 degrees
		<i>Roll</i>	0.064 degrees
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second
		<i>Loading</i>	0.019 meters
<i>Draft</i>		0.006 meters	
<i>Delta Draft</i>		0.010 meters	
<i>Vessel</i>	2803_Reson7125_LF_256		
<i>Echosounder</i>	Reson SeaBat 7125-B 200 kilohertz		
<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
<i>Navigation Position</i>	1.000 meters		

	<i>Timing</i>	<i>Transducer</i>	0.005 seconds	
		<i>Navigation</i>	0.005 seconds	
		<i>Gyro</i>	0.005 seconds	
		<i>Heave</i>	0.005 seconds	
		<i>Pitch</i>	0.005 seconds	
		<i>Roll</i>	0.005 seconds	
	<i>Offsets</i>	<i>x</i>	0.010 meters	
		<i>y</i>	0.010 meters	
		<i>z</i>	0.010 meters	
	<i>MRU Alignment</i>	<i>Gyro</i>	0.117 degrees	
		<i>Pitch</i>	0.059 degrees	
		<i>Roll</i>	0.059 degrees	
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second	
		<i>Loading</i>	0.019 meters	
		<i>Draft</i>	0.006 meters	
		<i>Delta Draft</i>	0.010 meters	
	<i>Vessel</i>	2804_Reson7125_HF_512		
	<i>Echosounder</i>	Reson SeaBat 7125 SV2 400 kilohertz		
	<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
			<i>Heave</i>	5.000 % Amplitude
0.050 meters				
<i>Pitch</i>			0.020 degrees	
<i>Roll</i>		0.020 degrees		
<i>Navigation Position</i>		1.000 meters		
<i>Timing</i>		<i>Transducer</i>	0.005 seconds	
		<i>Navigation</i>	0.005 seconds	
		<i>Gyro</i>	0.005 seconds	
		<i>Heave</i>	0.005 seconds	
		<i>Pitch</i>	0.005 seconds	
		<i>Roll</i>	0.005 seconds	
<i>Offsets</i>		<i>x</i>	0.010 meters	
	<i>y</i>	0.010 meters		
	<i>z</i>	0.010 meters		

	<i>MRU Alignment</i>	<i>Gyro</i>	0.267 degrees
		<i>Pitch</i>	0.128 degrees
		<i>Roll</i>	0.128 degrees
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second
		<i>Loading</i>	0.019 meters
		<i>Draft</i>	0.004 meters
		<i>Delta Draft</i>	0.010 meters
<i>Vessel</i>	2804_Reson7125_LF_256		
<i>Echosounder</i>	Reson SeaBat 7125 SV2 200 kilohertz		
<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
	<i>Navigation Position</i>	1.000 meters	
	<i>Timing</i>	<i>Transducer</i>	0.005 seconds
		<i>Navigation</i>	0.005 seconds
		<i>Gyro</i>	0.005 seconds
		<i>Heave</i>	0.005 seconds
		<i>Pitch</i>	0.005 seconds
		<i>Roll</i>	0.005 seconds
	<i>Offsets</i>	<i>x</i>	0.010 meters
		<i>y</i>	0.010 meters
		<i>z</i>	0.010 meters
	<i>MRU Alignment</i>	<i>Gyro</i>	0.267 degrees
		<i>Pitch</i>	0.128 degrees
<i>Roll</i>		0.128 degrees	
<i>Vessel</i>	<i>Speed</i>	0.080 meters/second	
	<i>Loading</i>	0.019 meters	
	<i>Draft</i>	0.004 meters	
	<i>Delta Draft</i>	0.010 meters	
<i>Vessel</i>	S221_Simrad-EM710_ICE		
<i>Echosounder</i>	Kongsberg Simrad EM710 ½°x 1° 100 kilohertz		

<i>TPU Standard Deviation Values</i>	<i>Motion</i>	<i>Gyro</i>	0.020 degrees
		<i>Heave</i>	5.000 % Amplitude
			0.050 meters
		<i>Pitch</i>	0.020 degrees
	<i>Roll</i>	0.020 degrees	
	<i>Navigation Position</i>	1.000 meters	
	<i>Timing</i>	<i>Transducer</i>	0.014 seconds
		<i>Navigation</i>	0.014 seconds
		<i>Gyro</i>	0.014 seconds
		<i>Heave</i>	0.014 seconds
		<i>Pitch</i>	0.014 seconds
		<i>Roll</i>	0.014 seconds
	<i>Offsets</i>	<i>x</i>	0.002 meters
		<i>y</i>	0.002 meters
		<i>z</i>	0.002 meters
	<i>MRU Alignment</i>	<i>Gyro</i>	0.044 degrees
		<i>Pitch</i>	0.074 degrees
		<i>Roll</i>	0.074 degrees
	<i>Vessel</i>	<i>Speed</i>	0.080 meters/second
		<i>Loading</i>	0.025 meters
		<i>Draft</i>	0.021 meters
		<i>Delta Draft</i>	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 “2017 HVF summary” report. This report is a compilation of vessel reports for all of the survey platforms used during the 2017 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 “2017 HVF summary” included with this report.

### C.1.1.3 Vessel Offset Correctors

<i>Vessel</i>	2801_Reson7125_HF_512		
<i>Echosounder</i>	Reson SeaBat 7125-B 400 kilohertz		
<i>Date</i>	2017-04-05		
<i>Offsets</i>	<i>MRU to Transducer</i>	<i>x</i>	-0.001 meters
		<i>y</i>	0.054 meters
		<i>z</i>	0.474 meters
		<i>x2</i>	N/A
		<i>y2</i>	N/A
		<i>z2</i>	N/A

	<table border="1"> <tr> <td rowspan="6"><i>Nav to Transducer</i></td> <td><i>x</i></td> <td>-0.001 meters</td> </tr> <tr> <td><i>y</i></td> <td>0.054 meters</td> </tr> <tr> <td><i>z</i></td> <td>0.474 meters</td> </tr> <tr> <td><i>x2</i></td> <td>N/A</td> </tr> <tr> <td><i>y2</i></td> <td>N/A</td> </tr> <tr> <td><i>z2</i></td> <td>N/A</td> </tr> <tr> <td rowspan="2"><i>Transducer Roll</i></td> <td><i>Roll</i></td> <td>0.000 degrees</td> </tr> <tr> <td><i>Roll2</i></td> <td>N/A</td> </tr> </table>	<i>Nav to Transducer</i>	<i>x</i>	-0.001 meters	<i>y</i>	0.054 meters	<i>z</i>	0.474 meters	<i>x2</i>	N/A	<i>y2</i>	N/A	<i>z2</i>	N/A	<i>Transducer Roll</i>	<i>Roll</i>	0.000 degrees	<i>Roll2</i>	N/A													
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		<i>y2</i>	N/A	
		<i>z2</i>	N/A	
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		<i>Roll2</i>	N/A	
<i>Vessel</i>	2803_Reson7125_LF_256			
<i>Echosounder</i>	Reson SeaBat 7125-B 200 kilohertz			
<i>Date</i>	2017-04-20			
<i>Offsets</i>	<i>MRU to Transducer</i>	<i>x</i>	-0.002 meters	
		<i>y</i>	0.026 meters	
		<i>z</i>	0.479 meters	
		<i>x2</i>	N/A	
		<i>y2</i>	N/A	
		<i>z2</i>	N/A	
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		<i>y2</i>	N/A	
		<i>z2</i>	N/A	
	<i>Transducer Roll</i>	<i>Roll</i>	0.000 degrees	
		<i>Roll2</i>	N/A	
	<i>Vessel</i>	2804_Reson7125_HF_512		
	<i>Echosounder</i>	Reson SeaBat 7125 SV2 400 kilohertz		
	<i>Date</i>	2017-04-19		
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<i>z</i>			0.477 meters	
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<i>Transducer Roll</i>	<i>Roll</i>	0.000 degrees																														
	<i>Roll2</i>	N/A																														
<i>Vessel</i>	S221_Simrad-EM710_ICE																															
<i>Echosounder</i>	Kongsberg Simrad EM710 ½°x 1° 100 kilohertz																															
<i>Date</i>	2016-06-27																															
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<i>Nav to Transducer</i>	<i>x</i>	0.000 meters
	<i>y</i>	0.000 meters
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	<i>x2</i>	0.000 meters
	<i>y2</i>	0.000 meters
	<i>z2</i>	0.000 meters
<i>Transducer Roll</i>	<i>Roll</i>	0.000 degrees
	<i>Roll2</i>	0.000 degrees

## C.1.2 Layback

Layback correctors were not applied.

## 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 minor but measurable 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 “2017 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 2017 field season. See the report "FA\_classHSL\_DynamicDraft" attached to this document for more information.

Although it was the original intention to use the class specific dynamic draft values as described in the "FA\_classHSL\_DynamicDraft" report for all Rainier Jensen launches, the values actually entered for the launches save 2803\_Reson7125\_LF\_256 (which uses the recommended values) were based upon an earlier version of the graph with slightly different values. These conflicting values differ from the recommended draft values by 1cm at four different speed values. These slight differences results in a dynamic draft curve virtually indistinguishable from the historic average and well within the historic highs and lows. Since this altered dynamic draft table can be expected to have a negligible effect on the final MBES data, the decision was made to retain these values and avoid the other issues that would be caused by editing and re-applying dynamic draft.

### C.2.2.2 Methods and Procedures

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

DDSSM for Rainier was determined on May 1, 2013 using the ellipsoidally-referenced method just outside of Birch Bay, Puget Sound, Washington. To reduce the effect of any potential current, reciprocal lines were

run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel’s speed through the water.

Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVF’s). 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 HVF’s contains sensor offset and dynamic draft correctors that pertain to this single acquisition system. Sensor offset and dynamic draft correctors were applied to bathymetric data in CARIS during post-processing.

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

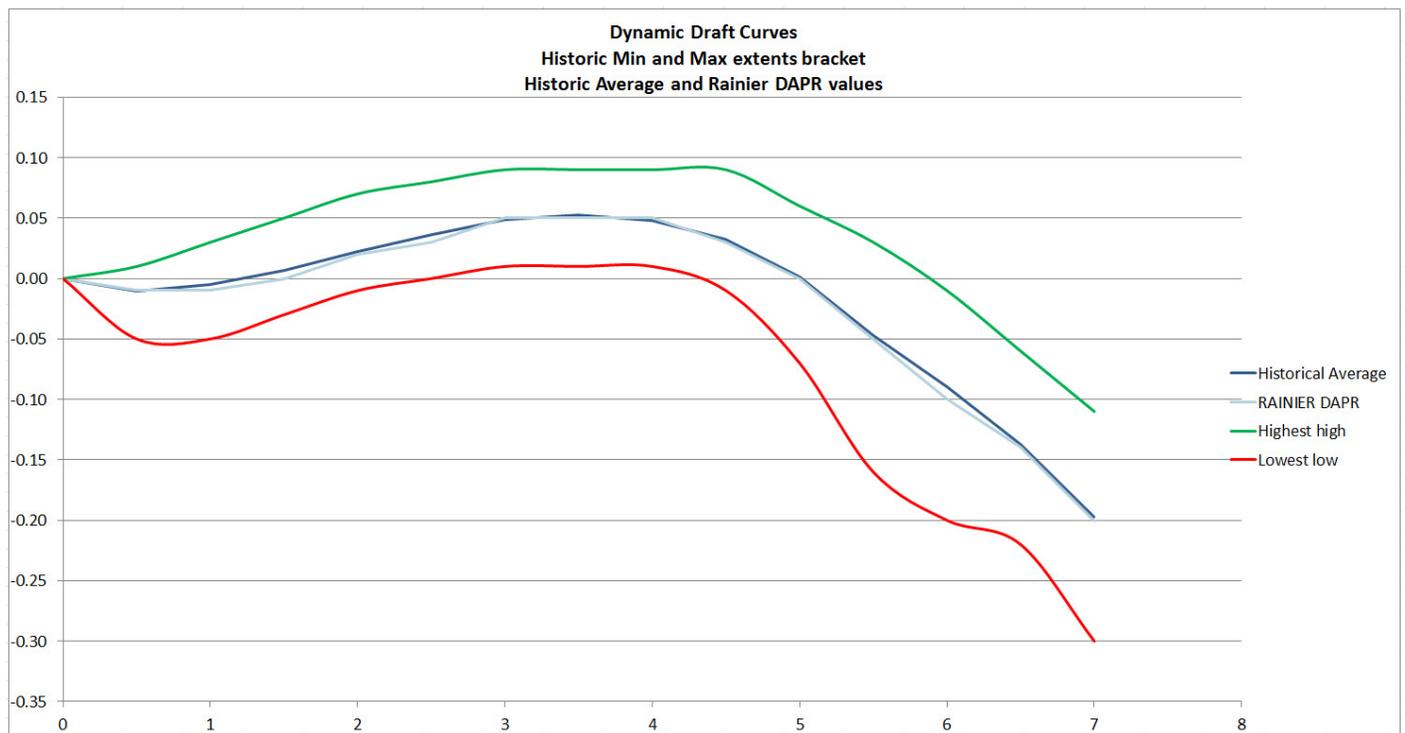


Figure 27: The historic dynamic draft graph showing the Rainier altered values (light blue) against the historic values (dark blue)

### C.2.2.3 Dynamic Draft Correctors

<i>Vessel</i>	2803_Reson7125_LF_256	
<i>Date</i>	2015-05-09	
<i>Dynamic Draft Table</i>	<i>Speed</i>	<i>Draft</i>
	0.0	0.00
	0.5	-0.01

	<i>Speed</i>	<i>Draft</i>
	1.0	0.00
	1.5	0.01
	2.0	0.02
	2.5	0.04
	3.0	0.05
	3.5	0.05
	4.0	0.05
	4.5	0.03
	5.0	0.00
	5.5	-0.05
	6.0	-0.09
	6.5	-0.14
	7.0	-0.20
<i>Vessel</i>	All Rainier Jensen survey launches but 2803_Reson7125_LF_256	
<i>Date</i>	2016-03-21	
	<i>Speed</i>	<i>Draft</i>
<i>Dynamic Draft Table</i>	0.0	0.00
	0.5	-0.01
	1.0	-0.01
	1.5	0.00
	2.0	0.02
	2.5	0.03
	3.0	0.05
	3.5	0.05
	4.0	0.05
	4.5	0.03
	5.0	0.00
	5.5	-0.05
	6.0	-0.10
	6.5	-0.14
7.0	-0.20	
<i>Vessel</i>	S221 (Rainier)	
<i>Date</i>	2013-05-01	

<i>Dynamic Draft Table</i>	<i>Speed</i>	<i>Draft</i>
	0.0	0.00
	0.5	-0.01
	1.0	-0.02
	1.5	-0.01
	2.0	0
	2.5	0.01
	3.0	0.03
	3.5	0.05
	4.0	0.08
	4.5	0.10
	5.0	0.13
	5.5	0.15
	6.0	0.17
	6.5	0.19
7.0	0.21	

## 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.

For Rainier:

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

Data was converted in CARIS HIPS using the regular HVF file which already has the heave, pitch, roll and timing values set to zero. True heave, water levels, the most recent dynamic draft, and sound velocity

profiles were applied and the data merged before cleaning via Swath Editor. Biases were determined using the CARIS HIPS Calibration tool by at least 5 individual testers. The multiple values determined for each bias by individual testers were examined by a reviewer, and obvious outliers rejected before an average was determined. This average value was then applied to the bias in question and applied to the data before moving on to the next bias determination. Bias values were determined in the following order; timing, pitch, roll, and finally yaw.

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

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

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

### C.3.3 System Alignment Correctors

<i>Vessel</i>	2801_Reson7125_HF_512	
<i>Echosounder</i>	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz	
<i>Date</i>	2017-03-30	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.670 degrees
	<i>Roll</i>	-0.223 degrees
	<i>Yaw</i>	-0.396 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.4 System Alignment Correctors

<i>Vessel</i>	2801_Reson7125_LF_256	
<i>Echosounder</i>	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
<i>Date</i>	2017-03-30	

<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.905 degrees
	<i>Roll</i>	-0.211 degrees
	<i>Yaw</i>	-0.563 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.5 System Alignment Correctors

<i>Vessel</i>	2802_Reson7125_HF_512	
<i>Echosounder</i>	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz	
<i>Date</i>	2017-04-19	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-1.244 degrees
	<i>Roll</i>	-0.212 degrees
	<i>Yaw</i>	0.440 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.6 System Alignment Correctors

<i>Vessel</i>	2802_Reson7125_LF_256	
<i>Echosounder</i>	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
<i>Date</i>	2017-04-19	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-1.244 degrees
	<i>Roll</i>	-0.212 degrees
	<i>Yaw</i>	0.440 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.7 System Alignment Correctors

<i>Vessel</i>	2803_Reson7125_HF_512	
<i>Echosounder</i>	Reson SeaBat 7125 (400kHz 512 Beams) 400 megahertz	
<i>Date</i>	2017-04-20	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.307 degrees
	<i>Roll</i>	0.175 degrees
	<i>Yaw</i>	-0.015 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.8 System Alignment Correctors

<i>Vessel</i>	2803_Reson7125_LF_256	
<i>Echosounder</i>	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
<i>Date</i>	2017-04-20	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.395 degrees
	<i>Roll</i>	0.187 degrees
	<i>Yaw</i>	-0.294 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.9 System Alignment Correctors

<i>Vessel</i>	2804_Reson7125_HF_512	
<i>Echosounder</i>	Reson SeaBat 7125 (400kHz 512 Beams) 400 kilohertz	
<i>Date</i>	2017-04-19	

<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.537 degrees
	<i>Roll</i>	0.712 degrees
	<i>Yaw</i>	-0.167 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.10 System Alignment Correctors

<i>Vessel</i>	2804_Reson7125_LF_256	
<i>Echosounder</i>	Reson SeaBat 7125 (200kHz 256 Beams) 200 kilohertz	
<i>Date</i>	2017-04-19	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	-0.537 degrees
	<i>Roll</i>	0.712 degrees
	<i>Yaw</i>	-0.167 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	0.000 seconds

### C.3.11 System Alignment Correctors

<i>Vessel</i>	S221_Simrad-EM710_ICE (CARIS HVF)	
<i>Echosounder</i>	Simrad EM710 (0.5x1) 100 kilohertz 100 kilohertz	
<i>Date</i>	2016-06-28	
<i>Patch Test Values</i>	<i>Navigation Time Correction</i>	0.000 seconds
	<i>Pitch</i>	0.000 degrees
	<i>Roll</i>	0.000 degrees
	<i>Yaw</i>	0.000 degrees
	<i>Pitch Time Correction</i>	0.000 seconds
	<i>Roll Time Correction</i>	0.000 seconds
	<i>Yaw Time Correction</i>	0.000 seconds
	<i>Heave Time Correction</i>	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 to 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 2017 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](mailto: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.

## ERS ERZT Separation Model and GPS tides

For the 2017 field season Rainier had the requirement to vertically reference survey data to the ellipsoid. This is achieved through the use of either a VDATUM or ERZT separation model. For all surveys conducted in projects OPR-P136-RA-17 (North Coast of Kodiak Island) and OPR-P337-RA-17 (Southern Alaska Peninsula), Rainier utilized the ERZT separation model method. For project M-N908-RA-17 (IOCM Olympic Coast NMS Mapping Project) Rainier used a VDatum separation model to realize chart datum via the ellipsoid.

Regional VDATUM models have been released for the continental United States, but not for Alaska due to of a lack of data. Because of this lack of Alaskan VDATUM models, personnel at the NOAA NOS Office of Coast Survey Development Lab developed the “poor man’s VDatum” (PMVD), a model that fills in the gaps in VDatum ellipsoid-chart datum separation (SEP) coverage using existing NOAA hybrid-geoid models with additional input from the Topography of the Sea Surface (TSS) model based on recovered bench marks and standard zoned tidal-datum models from the traditional hydrographic survey. Although

Rainier did not utilize the PMVD separation model as the primary method to realize chart datum via the ellipsoid it was used as a QC check for the ERZT separation model that was used .

The first step to produce an ERZT separation model is load delayed heave and apply 3D trajectory and associated uncertainty files (e.g. SBETs and RMS) to all lines in the survey and then compute GPS tides. The next step is to compute separation model between the ellipse and MLLW using the real-time vertical position measurements observed during survey relative to the water line and the loaded tide file. The resolution of the model is selected to be 100m which makes it easier to trace anomalies in the separation to a specific boat-day set of lines. If anomalies exist, it may necessary to re-examine the SBET file and either interpolate over any outliers or re-process the SBET file by another method. Once any issues with the 100m separation model are resolved, a new separation model with a resolution 1000m is generated to be used to compute GPS tides in CARIS. Generation of a relatively coarse 1000m separation model has the effect of “smoothing out” any slight differences in elevation data between days and/or boats as seen across an entire sheet. The final step is to merge the data with the GPS Tide option selected to reduce the sounding data to MLLW via the ellipse through the application of the computed GPS tides.

### **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:

OPR-P136-RA-17, North Coast of Kodiak Island, Alaska

Preliminary water levels are generated using the CO-OPS supplied Tidal Constituent And Residual Interpolator (TCARI) file P136RA2017.tc and Preliminary/Verified water levels from Kodiak Island, AK (945-7292). No subordinate stations were required for project OPR-P136-RA-17.

OPR-P377-RA-17, Cold Bay, Alaska

Preliminary water levels are generated using the CO-OPS supplied Tidal Constituent And Residual Interpolator (TCARI) file P377RA2017.tc and Preliminary/Verified water levels from King Cove, AK (945-9881). No subordinate stations were required for project OPR-P377-RA-17.

M-N908-RA-17, IOCM Olympic Coast NMS Mapping Project, Washington

Preliminary water levels are generated using the CO-OPS supplied Tidal Constituent And Residual Interpolator (TCARI) file N908RA2017.tc and Preliminary/Verified water levels from Westport, WA (944-1102), LaPush, WA (944-2396), Toke Point, WA (944-0910) and Cape Disappointment, WA (944-0581). No subordinate stations were required for project M-N908-RA-17.

## **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. Mid-season Velocipy was phased out and replaced by SSP Manager which performs the same functions as Velocipy as well as adding the World Ocean Atlas for extending casts, the ability to input data from Sippican XBT probes, as well as additional SV data export options.

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 subjectively 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.

In surveys with deeper waters, it may be advantageous to utilize Expendable Bathythermographs (XBTs). XBTs can be deployed while the ship is in motion and take measurements to about 750 meters, but only measure temperature. SSP Manager can use the temp data from the XBT, augment with salinity data from the World Ocean Atlas, and extend down to the bottom of the ocean with the WOA data. Such casts may then be applied to raw sonar data in addition to extending the MVP profiles using the reference cast function.

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 SPP Manager 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, CTD, XBT, and/or 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 2017 field season. All operations were conducted in accordance with the Office of Coast Survey Field Procedures Manual (April 2014 edition), NOS Hydrographic Surveys Specifications and Deliverables (April 2017 edition), and all Hydrographic Technical Directives issued through the dates of data acquisition. All departures from these standard practices are described in this Data Acquisition and Processing Report and/or the relevant Descriptive Reports.

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

Approved and Forwarded:

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Benjamin K. Evans, CDR/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:

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

Field Operations Officer:

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Scott E. Broo, LT/NOAA  
Field Operations Officer  
NOAA Ship *Rainier*

