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

# Data Acquisition & Processing Report

*Type of Survey* Hydrographic

*Project No.* 2011 *Rainier* field season

*Time frame* June - October 2011

LOCALITY

*State* Washington/Alaska

*General Locality* Strait of Georgia, WA
and West of Prince of Wales Island, AK

2011

CHIEF OF PARTY
Captain Donald W. Haines, NOAA

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DATE

# Data Acquisition and Processing Report
## NOAA Ship *Rainier* (s221)
2011 Field Season
Chief of Party: Captain Donald W. Haines, NOAA

## A. EQUIPMENT

This Data Acquisition and Processing Report describes both the survey equipment used and the standard methods for acquisition applied to the equipment used. Not necessarily all equipment described within this report was used during data acquisition for all projects and/or sheets. Data were acquired by the following *Rainier* survey vessels:

| Hull Number | Vessel type |
|---|---|
| 2801 | 28 foot Jensen survey launch |
| 2802 | 28 foot Jensen survey launch |
| 2803 | 28 foot Jensen survey launch |
| 2804 | 28 foot Jensen survey launch |
| S221 | 231 foot steel hydrographic ship |

Vessels S221, 2801, 2802, 2803, and 2804 are used to acquire shallow-water multibeam (SWMB) data and sound velocity profiles. Any vessel may be utilized for collecting bottom samples and detached positions (DPs). Vessel descriptions and offset measurements are included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package*.

Three different categories of echosounder systems are available for use by *Rainier* survey vessels. The individual system(s) chosen for use in a given area were decided at the discretion of the Hydrographer using the guidance stated in the Hydrographic Survey Project Instructions, the Hydrographic Surveys Specifications and Deliverables Manual (HSSDM), and the Field Procedures Manual, and depended upon the limitations of each system, the bottom topography, the water depth, and the ability of the platform vessel to safely navigate the area. These systems are described in the following section.

A complete description of all echosounder systems, positioning, and attitude sensors in addition to a complete inventory and list of serial numbers is located in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package.*

**Sounding Equipment:**

1. RESON 8125 Launch Shallow Water Multibeam (SWMB)

Vessel 1103 was originally intended as the platform for the Reson SeaBat 8125 but an internal battery explosion and subsequent acid erosion of the hull rendered that launch unusable for the entire field season. The decision was then made to hull mount the Reson SeaBat 8125 on vessel 2803.

The SeaBat 8125, with Option 033, Angle-Independent Imagery, is a 455 kHz multibeam system that uses high frequency focused near-field beam forming to measure relative water depths across a 120° swath. Each swath consists of 240 individual 0.5° x 1.0° beams. This system is capable of operating in depths from 4 meters to 60 meters, with varying range scale values dependent upon the depth of water and across-track slope. Surface sound velocity was measured using an Reson SVP 71 velocimeter and digitally input into the Seabat 8125 during acquisition.

In order to simplify SWMB surveying in the near-shore areas, the SeaBat 8125 is mounted with a 34° angle looking towards starboard. The transducer is attached with a custom made aluminum bracket bolted to the forward hull hardpoint on the starboard side. Unfortunately this exposed position subjects the 8125 transducer to both high drag during transit and potential rock strikes during shoreline verification. To reduce this risk, a maximum transit speed of 12kts was established for launch 2803 while the SeaBat 8125 was mounted. Under optimal conditions, 2803 can be run along the 30-foot contour parallel to shore during periods of high tide and produce near complete SWMB coverage between the 8 and 4 meter depth curves.

**Figure 1 Reson Seabat 8125 mounted on survey launch 2803**

2. RESON 7125 Launch Shallow Water Multibeam (SWMB)

Vessels 2801, 2802, 2803 and 2804 are equipped with a hull-mounted Reson SeaBat 7125-B, which 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 theoretical 220 m depth limit for full swath coverage. The 400kHz setting maximum range is 200m resulting in a theoretical 87m depth limit for full swath coverage. The transducer assembly consists of single flat-faced receiver array and two projectors, one for each frequency. These systems included the optional Reson SVP 71 surface sound velocity probe.

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

In the 200kHz mode the system has a beamwidth of 1° x 2° and in the 400kHz mode has a beamwidth of 0.5° x 1°. At 200kHz, the SeaBat 7125 generates 256 bathymetry soundings per ping. At 400kHz, the system generates 256 or 512 bathymetry soundings per ping. Typical settings used aboard *Rainier* are 256 sounding, equidistant in LF mode and 512 sounding, equidistant in HF mode.

3. Kongsberg EM 710 multibeam echo sounder

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 alongtrack beamwidth of *Rainier's* configuration is ½° with a receive beamwidth of 1°.  The number of beams is 256 or 128 respectively, with dynamic focusing employed in the near field. A high density beam processing mode provides up to 400 or 200 soundings per swath by using a limited range window for the detections. The beamspacing may be set to be either equiangular or equidistant. Rainier typically collects 256 beams per ping in equidistant mode.

The transmit fan is divided into three sectors to maximize range capability but also to suppress interference from multiples of strong bottom echoes. The sectors are transmitted sequentially within each ping, and uses 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.


**Figure 2  Kongsberg EM 710 sonar transducer housing on Rainier (S221)**

4. Lead Line

During shoreline verification, lead lines were used to acquire depths over rocks and other features too shallow to acquire soundings using echo sounders.  *Rainier* personnel calibrated lead lines in March and April of 2011.  Calibration reports are included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package.*

**Side Scan Sonar:**

1. Multibeam Echosounder Backscatter

Option 033 of the Reson 8125 SWMB system used aboard 2803 provides angle-independent imagery similar to fixed-mount side scan sonar (SSS). The Reson 7125 systems aboard 2801, 2802, 2803 and 2804 also acquired 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.

Current guidance from the Field Procedures Manual calls for field units to acquire and submit multibeam backscatter data in snippet mode whenever feasible. Reson “snippets” imagery are recorded at acquisition and are present in the raw data, but not processed or analyzed. Snippet data contains the amplitude data of each individual sonar beam in a swath, but there are problems, well-documented in the hydrographic literature, that reduces the efficacy of processing these data.

Backscatter data are collected by default for the EM710.

Due to problems encountered with the installation and configuration of the tilted Reson 8125 system, backscatter data for this system were not collected for the 2011 field season.

Although no formal processing of backscatter data were performed, backscatter data were periodically converted solely 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 directly to NGDC for archival purposes.

**Positioning Equipment:**

1. Applanix POS MV 320

Vessels 2801, 2802, 2803, 2804 and *Rainier* are equipped with Applanix POS/MV 320 (version 4) Position and Orientation Sensors to measure and calculate position. The POS/MV is a GPS-aided inertial navigation system, which provides a blended position solution derived from both an Inertial Motion Unit (IMU) and an integrated GPS 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 than either system could produce by itself.

Position accuracy is displayed in real time by the POS/MV software and was monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables were not exceeded. In addition, the POS/MV software displays HDOP and the number of satellites used in position computation. Data acquisition was generally halted when an HDOP of 2.5 was exceeded or the number of satellites available dropped 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 was not halted during short periods of time when the HDOP and number of satellites used exceeded stated parameters.

2. Horicon shore-side base stations

During hydrographic operations, *Rainier* maintains at least one GPS base station near the project area. Base station sites are chosen for both clear lines of site 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. Base station sites are also selected to fall within 20 kilometers of all data within the project area.

Each stations consist 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 Goedetic 2 GPS antenna is secured atop a Seco fixed-height GPS 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 Trimble data. Batteries and solar panels provide power.

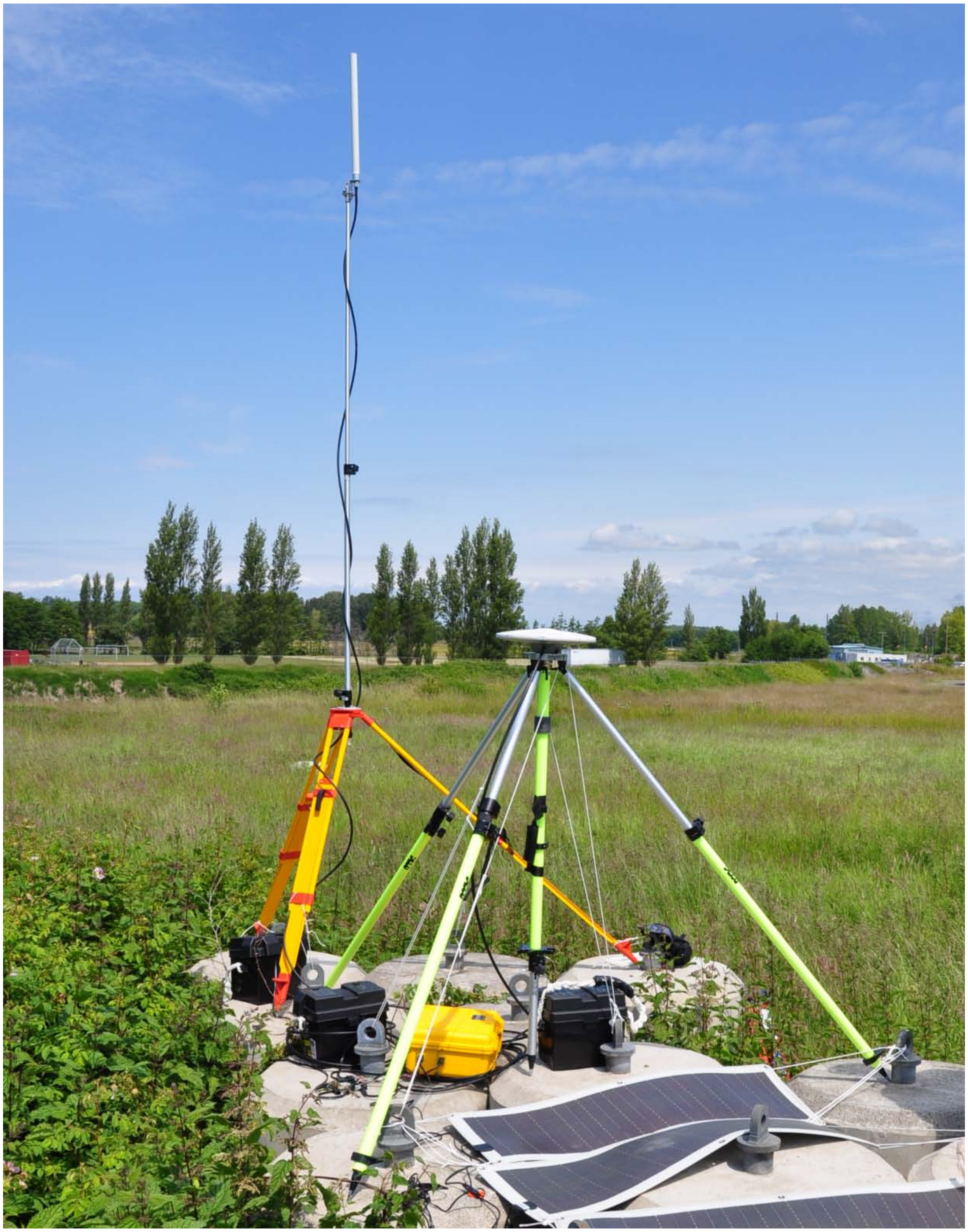


**Figure 3 An example of a horizontal control base station consisting of a fixed height GPS tripod, a UHF transmission antenna and a NetR9 receiver with associated batteries and solar panels.**

**Attitude Measurement Equipment:**

1. Applanix POS MV

*Rainier's* SWMB launches (1101, 2801, 2802, 2803 and 2804) are equipped with Applanix POS/MV Model 320 version 4 Position and Orientation System – Marine Vessel (POS/MV) sensors, which provide accurate navigation and attitude data to correct for the effects of heave, pitch, roll and heading. The POS generates attitude data in three axes (roll, pitch and heading) to an accuracy of 0.05° or better. Heave measurements supplied by the POS/MV maintain an accuracy of 5% of the measured vertical displacement 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 s (flat water) to 20 s (long period ocean swell), with values of 8 or 12 s typical.

Intermittent problems with the heading accuracy climbing above the ideal cutoff of 0.05° were observed, particularly with launches 2801 and 2802. The root cause of this problem has been hypothesized as a faulty antenna configuration on these launches. The POS/MV manual requires an antenna separation distance of at least 1m and recommends a distance between 2-5m. Unfortunately the first two new launches received by *Rainier* don't fully meet this requirement with 2801 having a separation of 1m and 2802 having a separation of 0.988m. This problem was addressed in the design of the next two new launches (2803 & 2804) which have an antenna separation of ~1.36m each. Heading accuracy was monitored by the launch crew and survey operations were temporarily suspended in the event that the error rose above 0.08°.

Applanix "TrueHeave" values were also recorded. The TrueHeave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. The TrueHeave data were applied to Reson bathymetry in CARIS HIPS post processing.

Full POSPac data were also recorded on vessels S221, 2801, 2802, 2803 and 2804. 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, (see section B for more information).

**Sound Speed Measurement Equipment:**

*Rainier* is equipped with a Rolls-Royce Group ODIM Brooke Ocean MVP200 Moving Vessel Profiler (MVP). This system consist 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 freefall near vertical through the water column recording sound velocity profiles. This enables *Rainier* to take SV casts without stopping the ship at the cost of not being able to collect casts with depths equal to the available cable length. 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 SV 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.

Vessel 2801 is equipped with a Rolls-Royce Group ODIM Brooke Ocean MVP30 MVP. This system consist 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 launch and periodically is allowed to freefall near vertical through the water column recording sound velocity profiles. This enables the launch to take SV casts without stopping the vessel at the cost of not being able to collect casts with depths equal to the available cable length. To take deeper SV casts and take full advantage of all the cable on the drum, the launch must stop. While stationary, 125 meter deep SV casts may be collected as opposed to a maximum of 50 meters deep when the launch is in typical survey mode and underway at 7 knots.

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. See section C, Corrections to Echo Soundings, of this report for more information on the actual sound velocity profilers used.


**Figure 4 The ODIM Brooke Ocean MVP200 Moving Vessel Profiler mounted aboard *Rainier***

**Software:**

All multibeam launches (2801, 2802, 2803 and 2804) recorded Reson shallow-water multibeam (SWMB) echosounder data, along with position and attitude data from the POS/MV using HYPACK, Inc.'s HYSWEEP®, an optional add-on module to HYPACK® 2010 hydrographic survey software. Data were logged in the ASCII (HSX Format) which includes full support for HYSWEEP survey features.

All SWMB data were processed using the 64-bit version of CARIS Hydrographic Information Processing System (HIPS) and Hydrographic Data Cleaning System (HDCS) software version 7.1 for the Microsoft Windows 7 environment.

For both the individual SeaCat profilers and *Rainier's* MVP, sound velocity profiles were computed from raw pressure, temperature, and conductivity measurements using the program Velocipy, supplied by the NOS Hydrographic Systems and Technology Programs N/CS11 (HSTP).

A complete list of software and versions is included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package*. Software updates were applied throughout the project to improve productivity and data quality. As software patches became available, they were tested by the Field Operations Officer, Chief Survey Technician, or other designated crew member. If tests resulted in satisfactory performance, the updates were installed on all affected workstations and tracked in a version control spreadsheet.

## B. DATA PROCESSING AND QUALITY CONTROL

### Project Management Overview

*Rainier's* data processing and quality control procedures are described in detail in the flow diagrams included in Appendix I. Roles, responsibilities, and the generalized project accomplishment procedure are summarized in this section.

<u>Project Planning</u>

Project Instructions received from Hydrographic Surveys Division (HSD) are reviewed by the Chief of Party (Commanding Officer), Field Operations Officer (FOO), and Chief Survey Technician (CST). Preliminary questions are addressed to HSD/OPS for clarification. The FOO then develops survey limits for each assigned sheet, and in consultation with the CO and CST, assigns each survey to a sheet team.

The sheet team is composed of as many as three people: The **Survey Manager** has responsibility for completion of the survey, including planning, data acquisition and processing, quality control, and creation of deliverables. Depending on the complexity of the survey, the Survey Manager is typically a commissioned officer, survey technician, or physical scientist with 6 months or more experience. **Survey Assistants** and/or **Survey Mentors** may also be assigned if required. **Survey Mentors** are assigned to particularly difficult survey areas or in the case of a less experienced Survey Manager. Mentors serve as intermediaries between the survey manager and the FOO, advising the Manager on survey planning and reviewing data and deliverables. Mentors generally have at least a year and a half of experience, and have demonstrated proficiency as Survey Managers themselves. **Survey Assistants** are junior commissioned or civilian personnel with less than one year's experience. They assist the Survey Manager with planning and data processing, and receive training from the Manager and Mentor. Notwithstanding the delegation of this authority to junior personnel, the FOO remains responsible to the Chief of Party for efficient, accurate, and thorough completion of all projects assigned to *Rainier*.

The Sheet Team reviews the Project Instructions, all other relevant guidance[1], and all available prior survey and source data. Prior survey bathymetry, if available, is used as a guide for planning survey acquisition to achieve the coverage required by the letter instructions. If shoreline verification is required for the survey, prior source data (Remote Sensing Division source, prior hydrographic

[1] "NOS Hydrographic Surveys Specifications and Deliverables", "OCS Field Procedures Manual", and Hydrographic Surveys Technical Directives.

survey data, lidar if available, and charted items) are compiled and deconflicted. The resulting survey data acquisition plan is reviewed by the FOO prior to implementation.

Data Acquisition

Field operations are planned by the FOO to utilize the appropriate platforms and sensors to meet the requirements of the survey team's acquisition plan. In the case of launch-based hydrography, actual data acquisition and field quality control is accomplished by a qualified **Launch Team.** At a minimum, this team will include a **Coxswain** (Person-In-Charge) and **Hydrographer-In-Charge** (HIC). The Coxswain is a member of the ship's crew who has met all requirements of coxswain certification for the vessel in use, and has been qualified by the Commanding Officer (CO) in consultation with the Chief Boatswain. The coxswain is responsible for the safe operation of the launch and the safety of the embarked personnel and equipment. The Hydrographer-In-Charge is a member of the ship's crew who has met the requirements for HIC qualification for the surveying techniques to be employed, and has been so qualified by the FOO in consultation with the CST and Chief of Party. The HIC is responsible for directing survey operations and operating survey equipment to efficiently complete the vessel's assigned mission and ensure data quality. Both Coxswains and HICs will generally have at least one year's experience prior to qualification for these positions. Additional qualified **Launch Crewmembers** may be assigned to a vessel as required for training purposes and/or to assist the HIC and Coxswain with survey operations.[2]

Each survey day begins and ends with a short meeting of personnel involved in that day's operations. Prior to deploying launches, the Commanding Officer and FOO brief the launch crews to ensure that they are aware of all safety issues, operational considerations, and mission for the day. The launch HICs are debriefed by the FOO in the evening to provide a firsthand account of the day's activities, any unusual features discovered, and any problems with data acquisition or launch systems.

Data Processing

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, night processing crew may be assigned to processing and QC checks of POSPac data. Final application of the POSPac data is the responsibility of the HorCon project manager and/or assistants. The HorCon project manager and the sheet manager work together to ensure SBETs were properly applying to the survey after post acquisition tasks are complete.

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

[2] For more information on personnel qualification standards, see NOAA Administrative Order 217-103, NMAO Small Boat Policy, and *Rainier* Standing Orders.

bathymetry. Survey documentation (including the Descriptive Report) is generated in conjunction with this review process.

Review and Quality Control

While quality control reviews are present throughout survey planning, data acquisition, and data processing, the final, complete review is accomplished once acquisition is complete and preliminary deliverables have been produced. Draft survey products are first reviewed by the Survey Mentor (if assigned) to check that *Rainier* standard practice has been followed, all applicable guidance has been observed, and all products meet specifications. Draft surveys are then forwarded to the CST and FOO for data review. The CST's review focuses on features and shoreline verification (if applicable), while the FOO's review focuses on bathymetric products. Feedback is passed back to the Manager, who makes the required changes. This process is repeated until the FOO is satisfied that all products are ready for review by the Chief of Party (CO). The CO reviews all products for consistency with ship and Coast Survey policy, and may also review constituent data to ensure data quality. The CO's comments are passed back through the FOO to the Survey Manager as necessary to address any issues encountered. Finally, once the survey is finalized, the data products are packaged by the CST for submittal to OCS.

**Multibeam Echosounder Data**

Shallow water multibeam data were monitored in real-time using the 2-D and 3-D data display windows in the on-screen display for the Reson SeaBat 8125. The Reson 7K Control Center online bathymetry data display was monitored in real-time for the Reson SeaBat 7125-B. 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 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 single depth range (see table #2) 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.

For *Rainier*, traditional line plans are still the norm although real-time coverage tools are used to assess SWMB coverage and find holidays in near real time. Lines are still in use to minimize the number of turns and course adjustments required for the relatively un-maneuverable *Rainier*.

Once the polygons were drawn using MapInfo 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 used (see table #2). The launch coxswain uses this 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 fill them in.

*Rainier's* primary bathymetric data review and quality control tool is the CARIS CUBE (Combined Uncertainty and Bathymetry Estimator) surface as implemented in HIPS version 7.1. The CUBE algorithm generates a surface consisting of multiple hypotheses that represent the possible depths at any given position. The CUBE 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 (see table #1).

- **Tide values measured** uncertainty value error ranges from 0.01m to 0.05 m is dependent upon the accuracy of the tide gauges used and the duration of their deployment. *Rainier* is using a value of 0.0 since 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 two of the Hydrographic Survey Project Instructions, Water Level Instructions. In section 1.3.1.1 Tide Component Error Estimation, the tidal error contribution to the total survey error budget is given 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 2 sigma, the value must be divided by 1.96 before it can be entered into CARIS (which expects a 1 sigma value).
- **Sound speed value measured** 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.
- **Sound speed value surface** 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 vessels 2801 2802, 2803 and 2804 to provide correctors for the flat face Reson 7125 and in the case of 2803 the Reson 8125. 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.

| Vessel | Tide values measured | Tide values zoning | Sound speed values measured | Sound speed values surface |
|---|---|---|---|---|
| S221_EM710 | 0.0 | Project specific | 3.0 | 0.05 |
| 2801_Reson7125 | 0.0 | Project specific | 3.0 | 0.15 |
| 2802_Reson7125 | 0.0 | Project specific | 3.0 | 0.15 |
| 2803_Reson7125 | 0.0 | Project specific | 3.0 | 0.15 |
| 2803_Reson8125 | 0.0 | Project specific | 3.0 | 0.15 |
| 2804_Reson7125 | 0.0 | Project specific | 3.0 | 0.15 |

***Table 1: TPU Values for Tide and Sound Velocity***

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.

After consultation with Kogsberg, *Rainier* modified the base device model file to account for the ½ by 1 degree system installed on the ship. This custom device model is included with the digital data submission of all surveys completed during the 2011 field season.

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 Hydrographic Surveys Division (HSD) 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. Table #2 illustrates how the advanced options configuration is manipulated based on the grid resolution of the CUBE surface being generated.

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

1. Convert the “raw” Reson data to the HDCS data format.
2. Load predicted tides.
3. Load and apply sound velocity files.
4. “Merge” data to apply position, attitude, vessel offsets, and dynamic draft correctors to bathymetry and compute the corrected depth and position of each sounding.
5. Compute TPU.
6. 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:

$$\text{Horizontal Error} > \pm(5\text{m} + 5\% \text{ of depth})$$

Vertical Error $> \pm\sqrt{\left[a^2 + (b*d)^2\right]}$, where "a" and "b" are defined as

| **Depth range** | **Depth a** | **Depth b** |
|---|---|---|
| 0-100m | 0.500 | 0.013 |
| Greater that 100m | 1.000 | 0.023 |

7. Add data to the master "QC" field sheet encompassing the entire survey.
   - "QC" Field Sheet naming convention: Hxxxxx_QC (e.g., H12345_QC)
   - Base surface are created in accordance with the depth ranges set forth in table #2.

| **Depth Range Filtering** | **CUBE Surface Resolution** | **BASE surface Advanced Options Configuration** |
|---|---|---|
| 0 – 20 m | 1.0 m | NOAA_1m |
| 18 – 40 m | 2.0 m | NOAA_2m |
| 36 – 80 m | 4.0 m | NOAA_4m |
| 72 – 160 m | 8.0 m | NOAA_8m |
| 144-320 m | 16.0 m | NOAA_16m |

***Table 2: Depth range vs. CUBE surface resolution***

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 and 16 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 greatest number of soundings and is also consistent with neighboring nodes).
- **Advanced Configuration** – As per table #2 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. The image designer can be used to visually enhance patterns and anomalies in CUBE surfaces, especially the standard deviation CUBE surface.
- 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. Swath editor is also useful when examining single lines of tilted 8125 data.
- 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 “allowed” according to HSD 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 clean, the “QC” field sheet CUBE surfaces are examined to ensure bottom coverage and plan additional lines or polygons to fill “holidays”. In addition the “QC” field sheet is used to compare adjacent lines and crosslines, for systematic errors such as tide or sound velocity errors, sensor error, sonar errors (consistent bad beams), vessel configuration problems, and noise. Any irregular patterns or problems are reported immediately to the FOO and the survey manager so that remedies can be found and applied before more data are acquired.

A coarse 8m resolution “Launch” BASE surface may also be maintained for use in the survey launches during data acquisition. The 8m resolution was selected to maintain smaller, easily transportable GeoTiff files.

- Naming convention is Hxxxxx_LaunchSafety_8m.
- The surface is created as a single resolution CUBE surface at 8m resolution.
- The CUBE surface is colored using a standardized custom *Rainier* generated CARIS *Colour Range* table (see table #3).
- The color pallet selected is intended to aid swift navigation over previously survey areas in addition to highlighting shallow areas.

| Depth Range | COLOR (CARIS) |
|---|---|
| -5 – 1 m | Pink |
| 1 – 2 m | Red |
| 2 – 4 m | Yellow |
| 4 – 8 m | Dark Yellow |
| 8 – 20 m | Lime |
| 20 – 40 m | Turquoise |
| 40 – 80 m | Blue |
| 80 – 160 m | Violet |
| 160 – 500 m | Grey |

***Table 3: Depth range vs. COLOR in use for launch safety DTMs***

Final review of the “QC” field sheet CUBE Surface is left to the Mentor or experienced survey manager who inspects areas with questionable shaded depth models and/or high standard deviation to ensure that no actual features were cleaned out. The use of large tiles is encouraged to track coverage of problems areas.

On occasion, the resolution of the CUBE surface may not be sufficient to capture the high point of a bathy feature. In less than 20m of water, any feature where the most probable accurate sounding was shoaler than the CUBE surface by greater than one half the allowable error under IHO S-44 Order 1 was considered inadequately captured by the CUBE surface. In greater than 20m of water, this allowable error was expanded to the full Order 1 error allowance at that depth. Although this may occur on irregular shoals or rock pinnacles, man-made features such as piles and wrecks are of particular concern. These features have very slender high points that extend far above the surrounding seafloor as well as the CUBE surface. To ensure that these features are properly represented, the shoalest point is flagged “designated” in CARIS. During the “finalization” process, the CUBE surface is forced to honor all soundings which have been flagged “designated”. In the case of a survey where the high points of many features are not being captured by the CUBE surface, (i.e. a boulder field), the hydrographer may decide to produce higher resolution CUBE surfaces to ensure that these features are being honored. Any such deviations from standard procedures will be noted in that survey’s Descriptive Report.

At the time of this report, Coast Survey has not approved multiple resolution BASE surfaces as a final deliverable. Although these surfaces are acceptable for field use, the algorithm produces artifacts at the resolution steps that are unsuitable for a final product. To circumvent this problem, single resolution CUBE surfaces were generated to be “cookie cut” and then reassembled to create the final CUBE surface from which depths are derived. Multiple CUBE surfaces are gridded using different resolutions for different depth ranges (see table #2).

Under ideal circumstances gridding should be done at the finest resolution that the data density will support. This theoretical maximum resolution was historically defined as three times the beam footprint size for a particular echosounder and depth combination. Current guidance (HSSD 5.2.2.2) states that 95% of the nodes in a cube surface shall contain at least 5 soundings per node. This minimum density of 5 soundings per node has experimentally been shown to be adequate to represent the depth of the seafloor while not being strongly influenced by a single erroneous sounding. The percentage of nodes meeting this specification is calculated using a Python script written by ST Weston Renoud of the NOAA Ship *Fairweather* and documented in the appropriate descriptive report.

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

With the advent of the CARIS CSAR framework and multi-threaded CUBE processing implemented in CARIS HIPS and SIPS 7.0, it is now practical to create a single field sheet that covers an entire survey. This ability fixes the shortcoming in previous versions of CARIS which limited CUBE surfaces to a maximum of approximately 25 million nodes. All resolution-specific CUBE surfaces are now created in this single sheet wide field sheet. The field sheet layout and CUBE surface resolutions are described for each survey in the Descriptive Report.

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

**H<registry #>_<resolution in meters>m**

(EX: "H12345_2m" refers to the two-meter resolution surface of survey H12345 )

Once the collection of CUBE surfaces accurately represent the surveyed bottom and it is certain that no further edits will be made, each CUBE surface is finalized using the resolution shown in table #2. All finalized CUBE surfaces are then combined at the coarsest resolution created for the data set to produce the final combined CUBE surface. The final combined CUBE surface is named by the following convention; Hxxxxx_Final_Combined.

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 in the field sheet serves to demonstrate that both SWMB coverage requirements are met and that systematic errors have been examined for quality-assurance purposes.

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 and manually compared to the mainscheme lines in CARIS subset mode. This qualitative QC comparison is discussed in the Descriptive Report for each survey.

**Feature Data**

Source shoreline data is typically supplied by N/CS31 in a single Composite Source file (CSF) in both S-57 .000 and .hob formats. Additionally, a Project Reference file (PRF) is supplied containing sheet limits, AWOIS items, and recommended bottom sample sites. The project-wide CSF file was trimmed to each sheet's individual survey limits and saved as both HOB and S-57 .000 files by the survey managers. The .000 format is used for the real time acquisition display in Hypack on the survey launches. The HOB file was used in CARIS Notebook and printed to create paper boat sheets for reference and note-taking during shoreline verification operations. This process is described in detail in the "CARIS Notebook" section below.

Shoreline verification was conducted during daylight periods near MLLW. A line was run along the shore approximating the position of the Navigational Area Limit Line (NALL). Thick near-shore kelp often dictated 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 was unsafe to approach 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 was run along the shore, the hydrographer both annotated the shoreline reference document and scanned the area for features to be addressed. All features with CARIS Notebook custom attribute “asgnmt” populated with 'Assigned' offshore of the NALL were fully investigated. 'Assigned' features inshore of the NALL were verified or DP’d for height if exposed but launches did not navigate inshore of the NALL to either disprove or investigate potential submerged 'Assigned' features. Feature are addressed in the following manner:

- Seaward of the NALL:
    - A feature found within 20 meters of the composite source position had its height/depth determined.
    - A feature outside 20 meters of the composite source position had its field position revised in addition to a heights/depth determination.
    - Features with any linear dimension greater than 0.5mm by 0.65mm at the scale of the largest scale chart were treated as an area and delineated.
    - New features not in the Composite Source file.
    - AWOIS items and other features specifically identified for investigation.

- Inshore of the NALL:
    - Navigationally significant features only, 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 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 were not generally considered navigationally significant. Areas with a high density of mooring buoys for these vessels were delineated, but the features themselves not individually positioned.

Terminology used for field annotation of the shoreline reference document during shoreline verification was as follows:

**“Noted”**

- The existence of a feature and its characteristics were confirmed from a distance, and its position appeared 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 were annotated on the shoreline reference document but carried no further forward in the processing pipeline. A "noted" annotation on a feature is not included in the H-Cell and adds little to PHB's current evaluation and verification process.

**" Verified "**

- The feature's position and characteristics were acquired and recorded either by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning was 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) was 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 20m of their source positions, but with incorrect or missing height or depth data.

**"New"**

- The feature's position and attributes (including height) were acquired and recorded either by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning was generally by DGPS methods.
- Appropriate for items seaward 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 (chart, DCFF, etc.) but was not visually observed in the field. Full disproval search (see below) was **not** conducted.
- Appropriate for:
  - Features above MHW, the absence of which can be proven visually from a distance.
  - Source features inshore of the limit of hydrography which are not observed, but whose presence on or absence from the survey will not affect safe navigation.
  - Any feature from source which was not seen, but for which full disproval search (see below) is impractical or unsafe.

**"Disproved"**

- The feature was present in source data, but was not located after a full search. "Full Search" means SWMB, VBES, 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 were 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 were taken of most objects which were 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.

In addition to the traditional shoreline techniques, RA3 (2803) may also be used to delineate the NALL with her ~34-degree tilted Reson 8125. During periods of high tide, 2803 acquired data while running parallel to shore. While running along the 30-foot curve was found to nicely fill in between the 4 and 8 meter curves with complete coverage, it also produced coverage far inside the NALL line (typically the 4-meter curve). Areas of kelp often prevented 2803 from reaching the 30-foot curve. Any additional soundings collected inshore of the NALL line 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 include it 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 ant 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 SWMB, 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 were renamed with an unique ID and moved into a single 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 HSTP, 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 is relegated to generating reports.

Features are selected for investigation by HSD OPS based on distance from MHW. Project instructions require that “All features with attribute asgnmt populated with 'Assigned' shall be verified even if they are inshore of NALL.” Contrary to the project instructions, OPR-N161-RA-11 had the attribute NINFOM populated with 'Assigned' instead of asgnmt.

In the event that an investigation inshore of NALL is called for, due to safety and potential equipment damage concerns, no *Rainier* launches ventured inshore of the NALL. If the feature in question was exposed, time and height attributes were assigned while driving past. If the feature was not evident while driving the NALL during shoreline verification, a remark of “inshore of NALL not investigated” was made with a recommendation of retain as charted.

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

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

All features marked as “primary” were 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 Field & Processing Branch Features Encoding Guide v1.3 and the CARIS “IHO S-57/ENC Object and Attribute Catalogue”. S-57 attribution is not required for those features flagged as "secondary" nor for unassigned features.

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

- **descrp - new** -- A new feature was identified during survey operations. The hydrographer recommends adding the feature to the chart.
- **descrp - update** -- The feature was found to be portrayed incorrectly on the chart. Update is also used in the case where the feature was found to be attributed incorrectly or insufficiently and is modified to reflect the additional or corrected attribution.
- **descrp - delete** -- The feature was disproved using approved search methods and guidelines. The hydrographer recommends removing it from the chart.
- **descrp - retain** -- The feature was found during survey operations to be positioned correctly or was not investigated. The hydrographer recommends retaining the feature as charted.

**CARIS Notebook**

The composite source shoreline feature file created at HSD and delivered with the project instructions 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.

In preparation for shoreline verification, the Survey Manager copied the project wide composite source file and cropped 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 Survey Manager next creates a composite shoreline reference document, the paper representation of the shoreline that will be used to write observations in the field. The **HXXXXX_Composite_Source.hob** file may be color coding to highlight any assigned features by using the NINFOM=Assigned field. The resultant color coded shoreline is then sent directly to the plotter from Notebook. 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.

In the field, CARIS Notebook was 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.**

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.

For surveys where limited shoreline verification was performed, DP/GPs and/or CARIS VBES/SWMB 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. Deleted sections of line features and/or any items fully deleted are flagged "delete". When objects were added or modified the SORDAT and SORIND fields were updated. Disproved features always maintain their original SORDAT and SORIND.

Investigation methods and results are described in CARIS Notebook under the S-57 attributes acronym "remrks". In the event that charting confusion could result from just the "remrks" field, specific recommendations are described under the S-57 attributes acronym "recomd". Any composite source features or shoreline not addressed during shoreline verification are left untouched.

All shoreline data is submitted in CARIS Notebook HOB file **HXXXXX_ Final_Features_File.hob**. The SORDAT and SORIND fields were filled in for any objects added to or modified in the Final Features HOB file.

**Pydro Feature Extraction & Reports**

Although feature attribution acquired in the field is typically entered directly into CARIS Notebook bypassing attribution in Pydro completely, Pydro is still used to generate reports on features. Typically after all edits have been completed in CARIS Notebook, the entire hob file is exported by **File → Export**

**→ to S57…** The resulting file is then loaded into Pydro **Data → (Re)insert → to S57 Feature Data (ENC_GPs).** A report is then generated **Reports → For Descriptive Report → DR via HSSD Extended S-57 Attributes.**

Soundings designated as DTONs are imported into Pydro from CARIS in order to generate the DTON report. AWOIS items are also tracked and resolved in Notebook in addition to generating the shoreline report which includes these items. Submerged features, such as rocks, wrecks and submerged piles designated in CARIS may also be brought into Pydro for attribution and eventual export to Notebook.

In addition to the Feature Report, Pydro was used to generate, Danger to Navigation Reports, and Requests for Approved Water Levels included with each survey.

**Raw GPS and BASE station OPUS data**

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

Initial processing requires:

- **Processing RAW GPS BASE station data –** 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 3 mb 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.

- **Single Base Station Processing –**

    1) Open Applanix POSPac™ Mobile Mapping Suite and set up the project
    2) Load the "true heave" POSPac 000 file (recorded on the launch)
    3) Bringing in the base station OPUS solution (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.

5) Both the SBET (in ITRF format) and smrmsg error data files are created.

- **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. A custom SBET in NAD 83 is created since the DGPS beacons broadcast in NAD83 and the default SBET created by POSPac is in ITRF.

SBETs are applied in CARIS by loading both the SBET files and error data files in smrmsg format. Every SBET file generated during single base station processing there is an associated smrmsg file.

1) **Process → Load Attitude/Navigation data…** Load the custom SBET files (NAD83). Import data for Navigation, Gyro, Pitch, Roll, and GPS Height are all selected for loading.

2) **Process → Load Error data…** Loads the smrmsg error data file. Import data for Position RMS, Roll RMS, Pitch RMS, and Gyro RMS are all selected for loading. Vertical RMS is not selected since HIPS will default to using the trueheave RMS values.

At this point the HIPS data must be remerged and the TPU recomputed. When computing TPU, “Error Data” should be checked in the “Uncertainly Source” window to ensures that *.smrmsg error data are used for the TPU computation.

For the 2011 field season, all surveys had their elevations referenced to the MLLW. No surveys are submitted with elevations referenced to the ellipsoid.

## C. CORRECTIONS TO ECHO SOUNDINGS

### Sound Velocity

Sound velocity profiles for *Rainier* survey launches were acquired with SeaBird Electronics SeaCat SBE19 and SBE 19Plus Conductivity, Temperature, and Depth (CTD) profilers (S/N 219, 281, 4039, 4114, 4343, and 4443) or with the Brooke Ocean Moving Vessel Profiler MVP-30 (S/N 007510 and 007511, main and spare). For ship acquisition, sound velocity profiles the Brooke Ocean Moving Vessel Profiler MVP-200 (S/N 007761)

Raw conductivity, temperature, and pressure data were processed using the program Velocipy which generated sound velocity profiles for CARIS in the .SVP format. Calibration reports and dates of the SeaCat profilers and MVPs are included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package*. SeaCat profilers were last calibrated in the winter of 2009 and, due to budget constraits, were not recalibrated in 2011. Seabird states the calibrations are good until the instruments are placed in the water, and with permission from Hydrographic Surveys Division Operations branch, a sound speed profile comparison was conducted between a calibrated Fairweather SeaCat (SN 6122) and all of Rainier’s SeaCat instruments. It was determined that sound speed profiles acquired by all *Rainier* SBE19 and SBE19Plus instruments were consistent with *Fairweather’s* SBE 19Plus sound speed profiles.

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 as strongly recommended in the NOS Hydrographic Surveys Specifications and Deliverables manual. 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.

The Reson 7125 SWMB systems utilized on vessels 2801, 2802, 2803 and 2804 require a sound velocity probe to be interfaced with the sonar processor for use in projector steering computations. A Reson SVP 71 surface sound velocity probe is utilized to feed real time SV values directly into the 7-P Sonar Processing Unit.

The Reson 8125 SWMB system utilized on vessel 2803 also requires a sound velocity probe to be interfaced with the sonar processor for use in projector steering computations. A Reson SVP 71 surface sound velocity probe already in place for use by the Reson 7125 SWMB system on 2803 was also used to feed real time SV values for the Reson 8125 SWMB system via the 81-P Sonar Processor 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. Casts are collected every 15 to 30 minutes dependent on local conditions. 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.

MVP casts sent directly to the Kongsberg EM 710 are processes in SIS and are applied to all subsequent SWMB data. This method has the drawback that the MVP cast taken prior to the collection SWMB data will always be applied rather than the SV cast that is closest. This shortcoming is circumvented by post applying SV data to all EM 710 data in CARIS HIPS/SIPS.

All sound velocity profiles for CARIS, both CTD and MVP, are concatenated into a sheet-wide file in order of ascending time/date and saved in the root directory of each sheet's SVP directory. This concatenated file is 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**.

**Vessel Offsets and Dynamic Draft Correctors**

The table below shows when the vessel offsets and dynamic draft correctors used for this project were last determined. A full description of the methods and results employed for each vessel is included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package.*

| Vessel Hull Number | Date of Static Draft and Transducer Offset Measurements | Method of Settlement and Squat Measurement | Date of Settlement and Squat Measurement | Location of Settlement and Squat Measurement |
|---|---|---|---|---|
| S221 | October 2010 | Ellipsoidal Reference | June 7, 2011 | Lake Washington, WA |
| 2801 | May 2011 | Ellipsoidal Reference | April 25, 2011 | Lake Washington, WA |
| 2802 | May 2011 | Ellipsoidal Reference | April 25, 2011 | Lake Washington, WA |

| | | | | |
|---|---|---|---|---|
| 2803 | May 2011 | Ellipsoidal Reference | April 27, 2011 | Lake Washington, WA |
| 2803 Reson 8125 | September 2011 | Ellipsoidal Reference | April 27, 2011 | Lake Washington, WA |
| 2804 | May 2011 | Ellipsoidal Reference | May 11, 2011 | Lake Washington, WA |

***Table 4: Dates of measurements (transducer offsets and settlement – squat)***

Settlement and squat observations were conducted for *Rainier* (S221) and launches 2801, 2802, 2803 and 2804 using the ellipsoidal referenced method. *Rainier* followed the procedure as outlined in section 1.4.2.1.2.1 of the FPM. Data were analyzed using the Pydro macro ProcSBETDynamicDraft.py as detailed in the NOAA Ellipsoidally Referenced Survey (ERS) SOP in the chapter 4 of the FPM appendices to produce delta draft vs. speed curves.

For the ellipsoidally referenced dynamic draft measurement method as utilized by *Rainier*, the launch was run with a constant line heading while speed was increased in two-knot increments from clutch ahead to fourteen knots in two-minute intervals. A five minute rest period was placed between the runs. POSPac data was recorded as soon as the system was brought up and throughout the entire duration of the dynamic draft measurement. The same procedure was utilized for the *Rainier* herself.

Following acquisition, the POSPac data recorded by the POS/MV was imported into the POSPac MMS software suite and processed using Single Base processing. Data from the national Geodetic Survey CORS station SEAI, operated at Sand Point, was selected as the Base Station. The resulting SBET was exported as an ASCII file, which was processed using the python processing script developed by ENS Glen Rice. Dynamic draft curves and delta draft value tables were then generated and entered into the CARIS dynamic draft table.

During the 2007-2008 winter repair period, National Geodetic Survey's Geodetic Services Division personnel conduct spatial relationship surveys on two *Rainier* launches (2801 and 2802). These measurements, in addition to dimensional blueprints and technical schematics from sonar manuals were used to determine each vessels' offsets. Following *Rainier's* MRP in 2010 - 2011 spot checks of these vessel offsets and static drafts were measured using steel tapes and a LEICA laser distance meter but no significant differences were observed. These results were not unexpected since no significant changes were made to vessels 2801 or 2802 during the winter repair period.

*Rainier* acquired two more new launches (2803 and 2804) for the 2009 field season and arrangements were made for personnel from the National Geodetic Survey's Geodetic Services Division to return and conduct spatial relationship surveys. Vessels 2803 and 2804 were pulled out of the water and put up on blocks in order to determine the spatial relationship of various sensors, the multibeam transducers, and reference points in relation to the POS/MV IMU. Unfortunately at the time this survey was conducted, the transducer arrays of the SWMB systems were not yet installed on these two launches due to the need for some additional grinding and welding on the hulls. Two reference points (FORE and AFT) were positioned adjacent to the sonar rack assembly well in anticipation of the sonar installation at a later date. *Rainier* personnel used these reference points and steel tapes to position the SWMB transducers once they were installed in their final position. These measurements, in addition to dimensional blueprints and technical schematics from sonar manuals were used to determine each vessels' offsets. Assuming that there has been no major change to configuration, offset measurements are spot checked on an annual basis as part of the system readiness\hydrographic systems readiness review.

During the *Rainer's* 2010-2011 major repair period, in conjunction with the installation of the new Kongsberg EM 710 multibeam system, Westlake Consultants, Inc. was contracted to conduct a measurement and alignment report. The spatial relationship between the ship's granite block, IMU mounting plate, transducer array, POS/MV antennae, and multiple ship reference points were all determined. Using these ship reference points *Rainier* crew determined two additional reference points atwartship of the IMU, to port and starboard. These two points and a weighted tape were used to determine the waterline of the ship prior to acquiring ship hydro.

For the 2011 field season an aluminum mounting bracket was commissioned to affix a Reson 8125 to RA3 (2803) at a ~34° angle to starboard. This mounting bracket utilized the pre-existing hard mounting points built into the hull for instrument sleds. Offsets to the Reson 8125 for vessel 2803 were measured from the FORE and AFT reference points on the keel using both steel tapes and a LEICA laser distance meter. The mounting angle of the transducer was checked with a Brunton clinometer.

Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVFs). Survey platforms which mount more than one acquisition system or use sonar systems with multiple frequencies have a separate HVF associated with each individual acquisition method available. Each of these HVFs contains sensor offset and dynamic draft correctors that pertain to this single acquisition system. Sensor offset and dynamic draft correctors were applied to bathymetric data in CARIS during post-processing. Vessel offset diagrams and dynamic draft tables are included in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package*. The HVFs themselves are submitted with the digital HDCS data.

The following table lists the HIPS Vessel File used for each available sonar system:

| HVF name | Survey Vessel & System Type |
|---|---|
| S221_Simrad-EM710.hvf | NOAA Ship Rainier, SWMB using Simrad EM 710 |
| 2801_Reson7125_HF_512 | Jensen hull 2801, SWMB using Reson 7125, 400kHz, 512 beams |
| 2801_Reson7125_LF_256 | Jensen hull 2801, SWMB using Reson 7125, 200kHz, 256 beams |
| 2802_Reson7125_HF_512 | Jensen hull 2802, SWMB using Reson 7125, 400kHz, 512 beams |
| 2802_Reson7125_LF_256 | Jensen hull 2802, SWMB using Reson 7125, 200kHz, 256 beams |
| 2803_Reson7125_HF_512 | Jensen hull 2803, SWMB using Reson 7125, 400kHz, 512 beams |
| 2803_Reson7125_LF_256 | Jensen hull 2803, SWMB using Reson 7125, 200kHz, 256 beams |
| 2803_Reson8125 | Jensen hull 2803, SWMB using hull mounted Reson 8125 |
| 2804_Reson7125_HF_512 | Jensen hull 2804, SWMB using Reson 7125, 400kHz, 512 beams |
| 2804_Reson7125_LF_256 | Jensen hull 2804, SWMB using Reson 7125, 200kHz, 256 beams |

***Table 5: List of HVFs used for the 2011 field season.***

**Heave, Pitch, Roll and Heading, Including Biases and Navigation Timing Errors**

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's* SWMB equipped survey launches utilize a data time synchronization method known as "precise timing" as described in Section 3 of the OCS Field Procedures Manual. This synchronization significantly reduces latency magnitude and variability, producing data which is both horizontally and vertically more accurate.

*Rainier's* SWMB equipped survey launches utilize a heave filter integration method known as "TrueHeave" as described in Section 3 of the OCS 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: 2011_285_2801.000). TrueHeave files are transferred to the "POSMV" folder of the CARIS preprocessed data drive (ex: H:\OPR-O190-A-11\H12289\POSMV\2801(RA-4)\DN265 contains TrueHeave data acquired by vessel 2801 on day number 265 for sheet H12289) for later submission to the PHB. In the event of computer crashes, multiple POS files have their names appended with "A", "B", and so on so that the order they were collected. After regular CARIS data conversion this TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw data.

It is standard procedure to start TrueHeave logging at least 5 minutes before starting bathymetric data acquisition and letting it run for at least 5 minutes afterward. This is required because the filter which produces the true heave values looks at a long series of data before and after the actual acquisition time of bathymetric data to create the baseline for the appropriate true heave calculation. If there is a problem with the TrueHeave data, the utility "fixTrueHeave" was run from the command line with the following context: **"fixTrueHeave <trueheave filename> -trim"**. This produces a new file with the same base name, but with the suffix "fixed" appended. This new ".fixed" file is then applied to the appropriate lines in HIPS.

On August 4, 2011 (DN216), RA6 (2804) experienced a failure or her TSS POS/MV system. The problem was eventually traced to a bad inertial measurement unit (IMU) which was replaced with the IMU from the disabled RA2 (1103). This transfer necessitated an new patch test for RA6 which was conducted on August 6, 2011 (DN218).

On September 28, 2011 (DN271), RA6 (2804) experienced data artifacts which affected data quality. The problem was eventually traced to a faulty receiver unit. This unit was replaced with the receiver from RA3 (2803) which was being used as a platform for the tilted 8125. This change necessitated an new patch test for RA6 which was conducted on October 5, 2011 (DN278).

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in the *2011 NOAA Ship Rainier Hydrographic Readiness Review Package*.

All vessel 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.

### Water Level Correctors

For daily processing, soundings were reduced to Mean Lower-Low Water (MLLW) using predicted water levels files supplied with the project instructions. The predicted water level data were applied to the survey depths in CARIS using height ratio and time correctors from a preliminary CO-OPS provided zone definition file.

After the conclusion of data acquisition, water levels are applied to the soundings using one of two methods, verified observed water levels using height ratio and time correctors from a CO-OPS supplied zone definition file or TCARI tides. TCARI tides are the preferred method but zoned tides using verified observed water levels may be used if the required TCARI grid is unavailable for the project.

Refer to individual Descriptive Reports for further information regarding water level correctors specific to each survey.

**D. APPROVAL**

As Chief of Party, I have ensured that standard field surveying and processing procedures were followed during this project. All operations were conducted in accordance with the Office of Coast Survey Field Procedures Manual (May 2011 edition), NOS Hydrographic Surveys Specifications and Deliverables (April 2011 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:

p.p. David O. Neander, CAPT/NOAA
on behalf of
Donald W. Haines, CAPT/NOAA
E.J. Van Den Ameele, 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:

James B. Jacobson

Digitally signed by James Jacobson
Reason: I am the author of this document
Date: 2012.04.03 16:19:16 -07'00'

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

Field Operations Officer:

OHauser LT/NOAA 2012.04.04 08:12:59 -07'00'

Olivia A. Hauser, LT/NOAA
Field Operations Officer
NOAA Ship *Rainier*

# APPENDIX I

## Data Processing Flow Diagrams

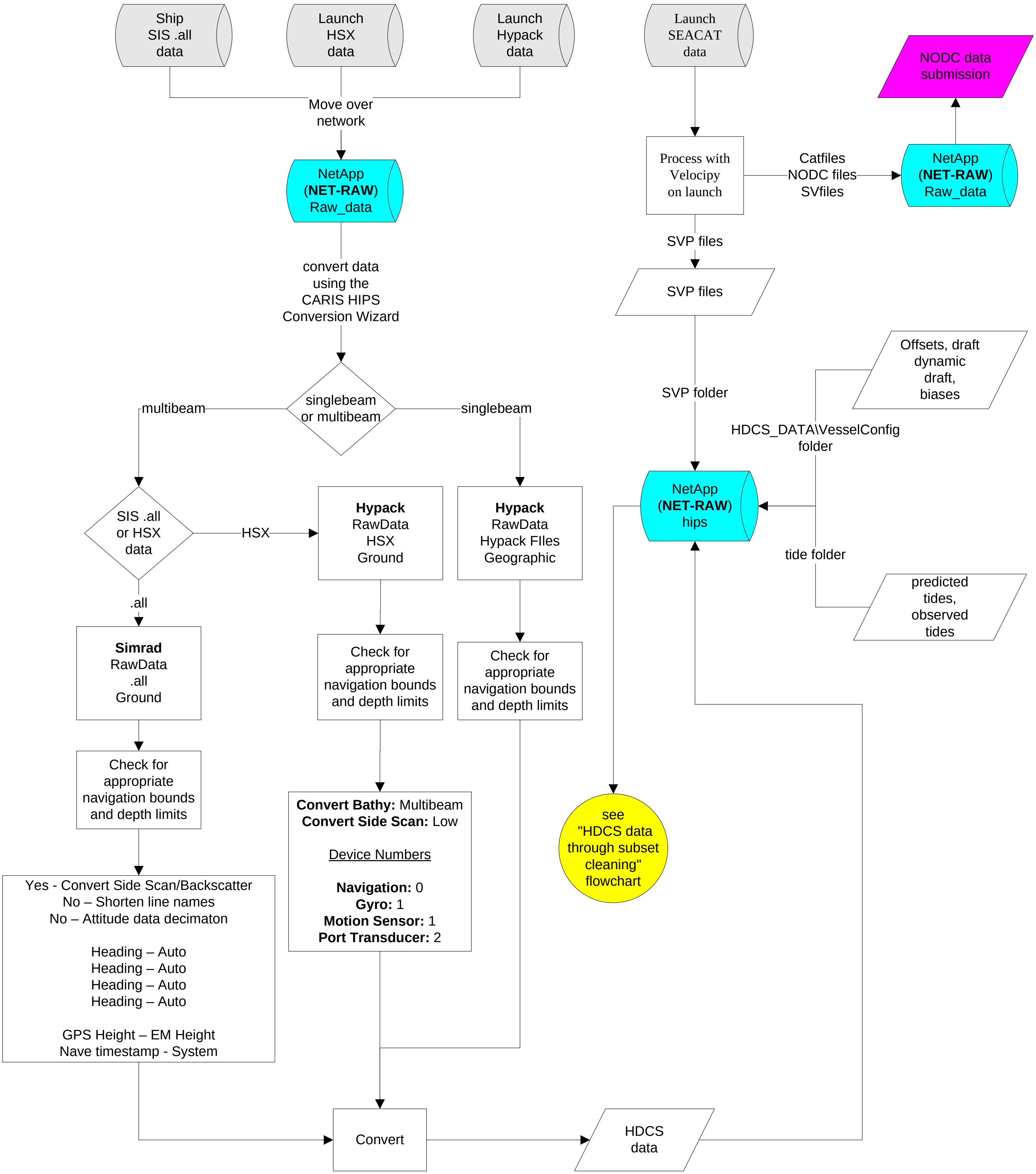
## Offsets

## Dynamic Draft

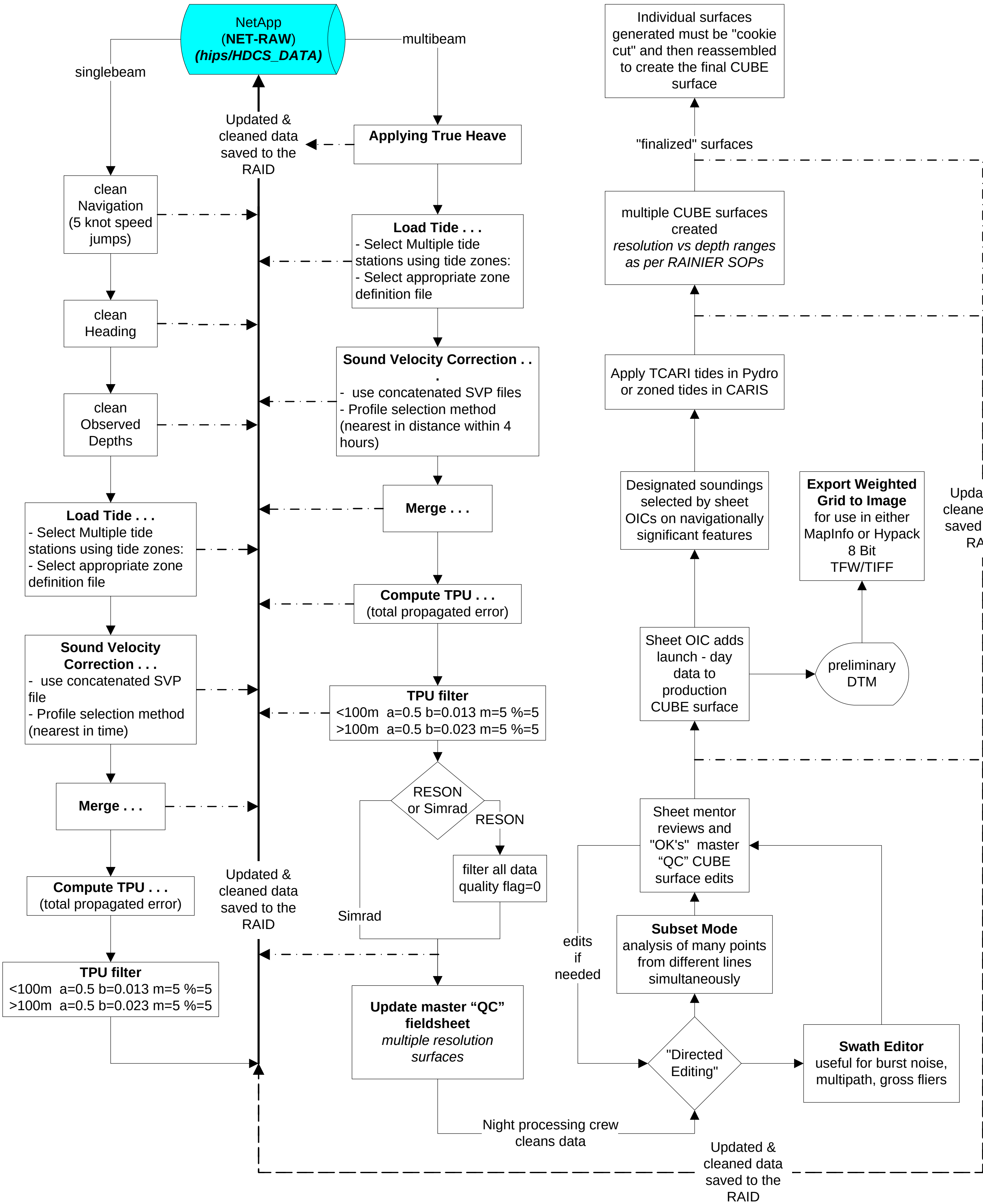
## Patch Tests

# Data Processing Flow Diagrams

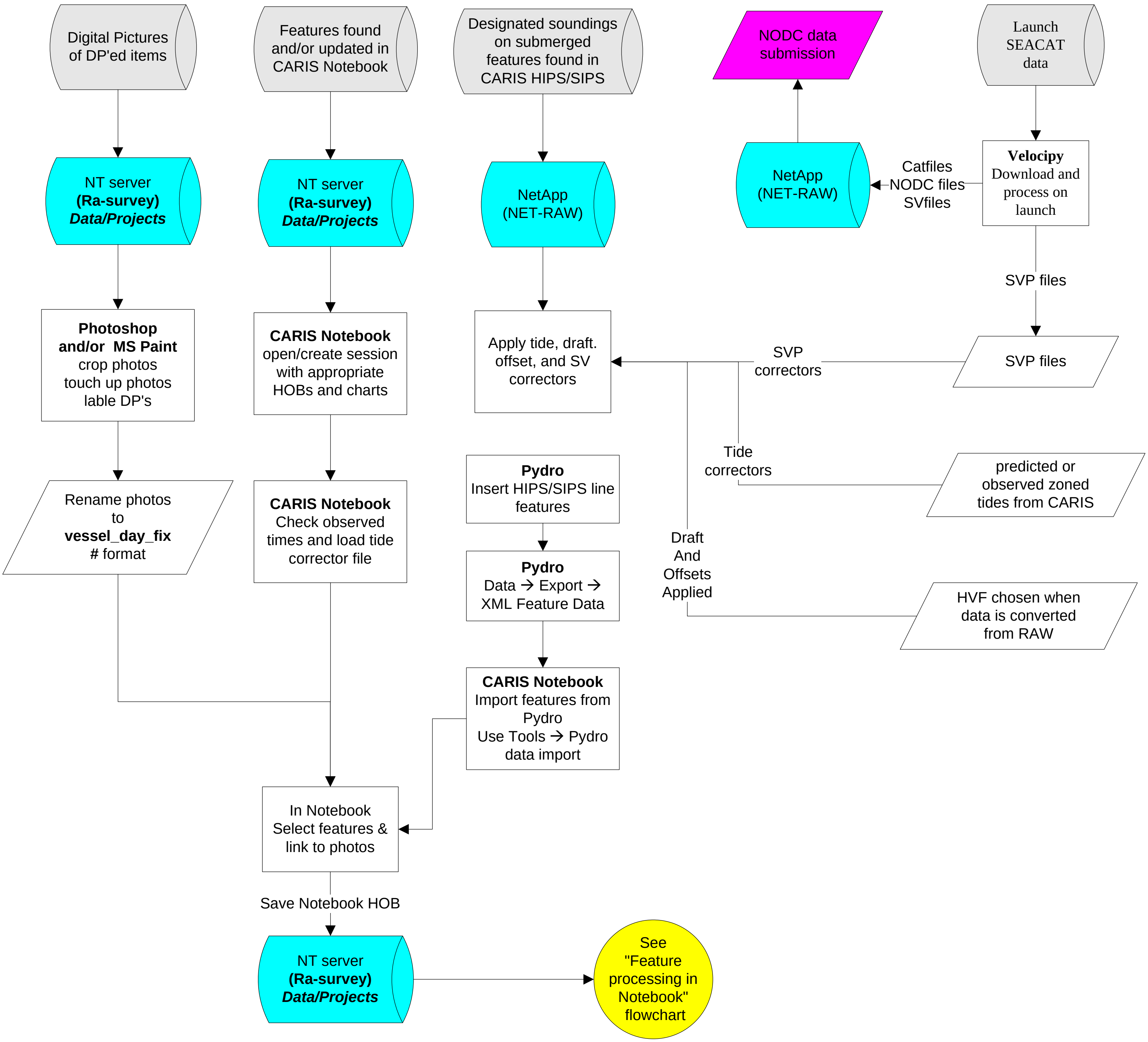
# Raw sounding data to HDCS



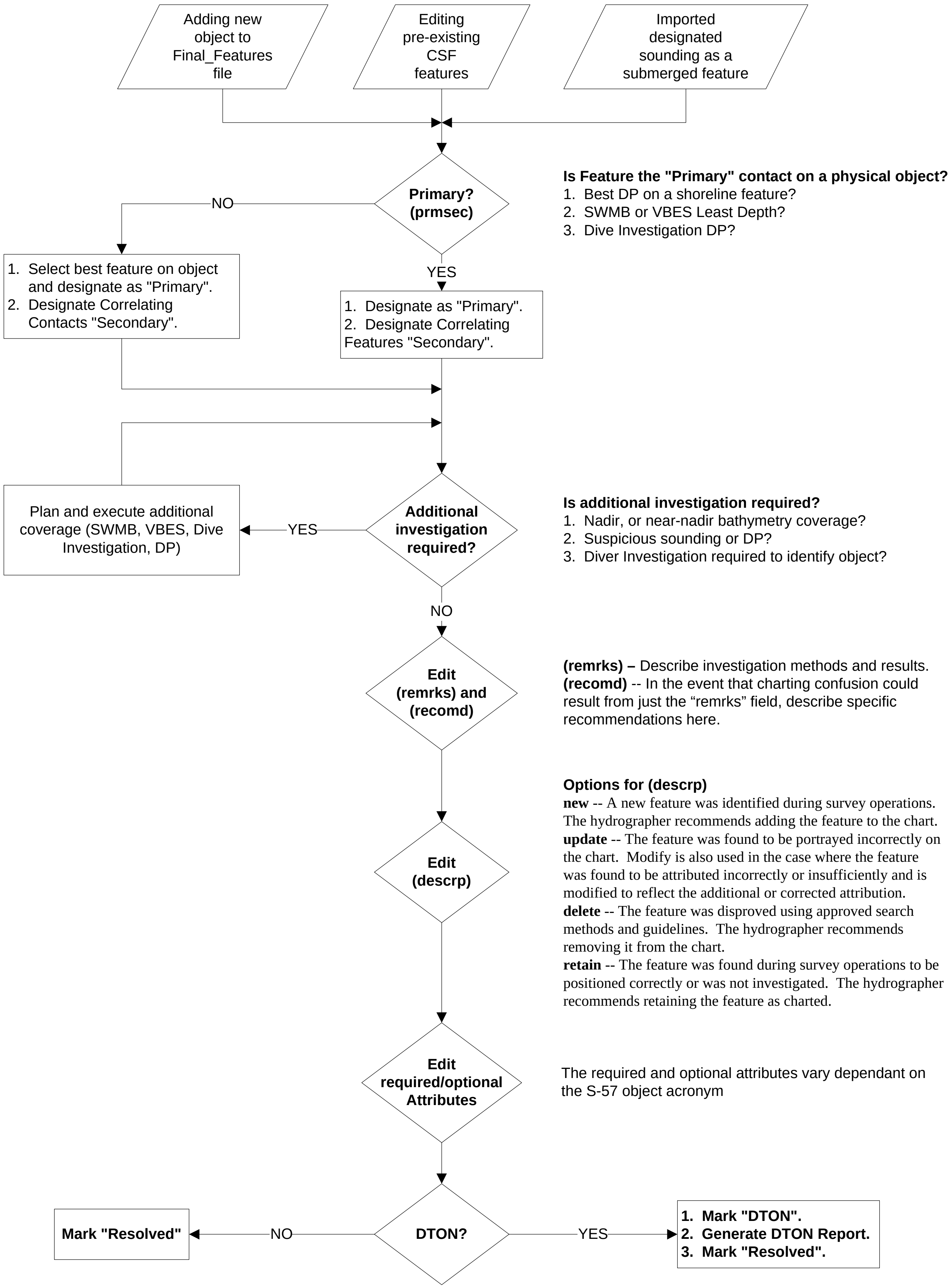
# HDCS data through subset cleaning



# Shoreline processing (Raw DP's to Pydro)



# Feature processing in Notebook



# Offsets

# HULL 2801 (RA4) VESSEL OFFSET MEASUREMENTS CERTIFICATION REPORT 2011

**Vessel**: Hull 2801 (RA4) 28 ft. Aluminum Jensen Survey Launch
**Sonar / Instrument / etc.**: Reson 7125
**Written By:** CST Jacobson, HAST Walsh
**Report Date:** 4/20/11

## Background:

The following report gives a technical description of how vessel 2801 offset measurements were derived so that future surveys may accurately reproduce these results.

During the 2007-2008 winter import, 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 RP (Reference Point) on the POS/MV IMU (Inertial Motion Unit).

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.

## Offset Re-verification Personnel, Location, and Date:

**Personnel**: HAST Walsh, Ens Manda
**Location**: Sand Point, WA
**Date**: 4/12/11

Using reference marks and benchmarks established by the 2008 NGS survey, *Rainier* personnel were able to re-verify the position of the mounting plate to which the Reson projectors are attached, the IMU, as well as the GPS antennas.

The measured position of the mounting plate and IMU differed by less than 1cm compared to the NGS surveyed position. The measured position of the GPS antennas differed ~1cm compared to the NGS surveyed position. Method of verification utilized steel tapes, plum-bobs, and carpenter squares.

## Waterline Offset Measurement Personnel, Location, and Date:

**Personnel**: ST Wilson, HAST Walsh
**Location**: Sand Point, WA
**Date**: 4/20/11
**Method**: The distance from the waterline to the deck was determined by measuring directly from the deck to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. Both the port and starboard measurements were taken and averaged together for a final value.

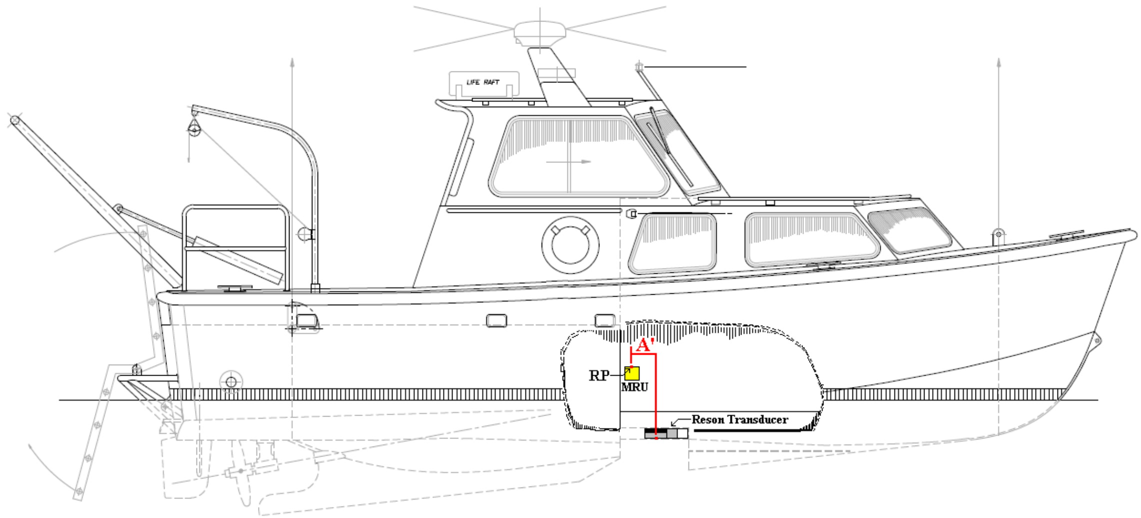



*Figure 1 Side view of 2801 (RA-4)*

A' – The distance from sonar head reference center to RP cannot be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, or the Reson 7125 manual.

| 200kHz | 400kHz | |
|---|---|---|
| 0.3520 | 0.3520 | average of distances between the two Plate RMs and the IMU |
| -0.0350 | -0.0350 | distance from plate RM to bolt-hole |
| -0.0170 | -0.0170 | bolt-hole to edge of Reson receiver |
| -0.1050 | -0.1050 | thickness of Reson receiver |
| -0.1400 | -0.1425 | distance from the end of Reson projector to the physical center |
| 0.0550 | 0.0525 | The distance from sonar reference center to RP |

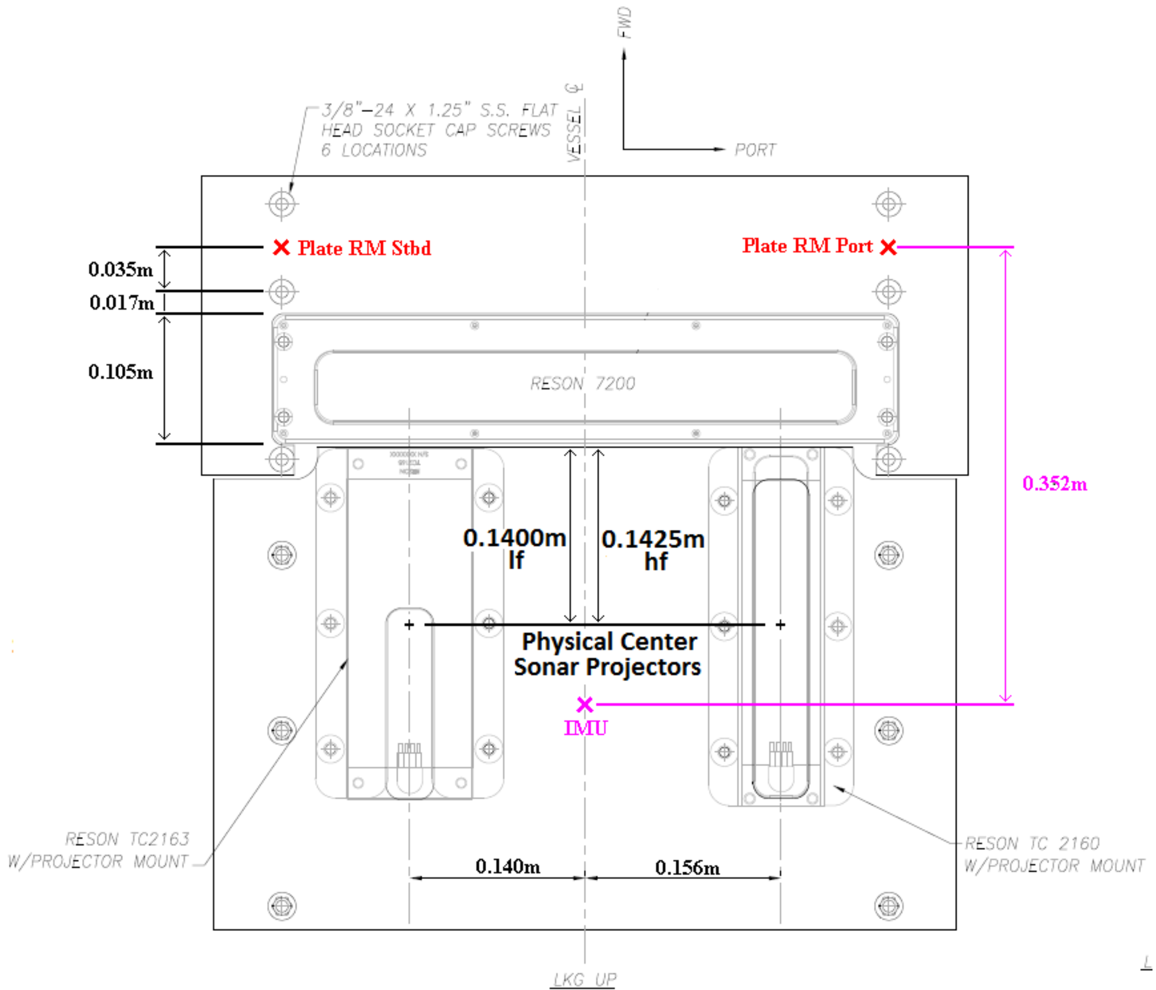



***Figure 2 The Reson 7125 mounting bracket***

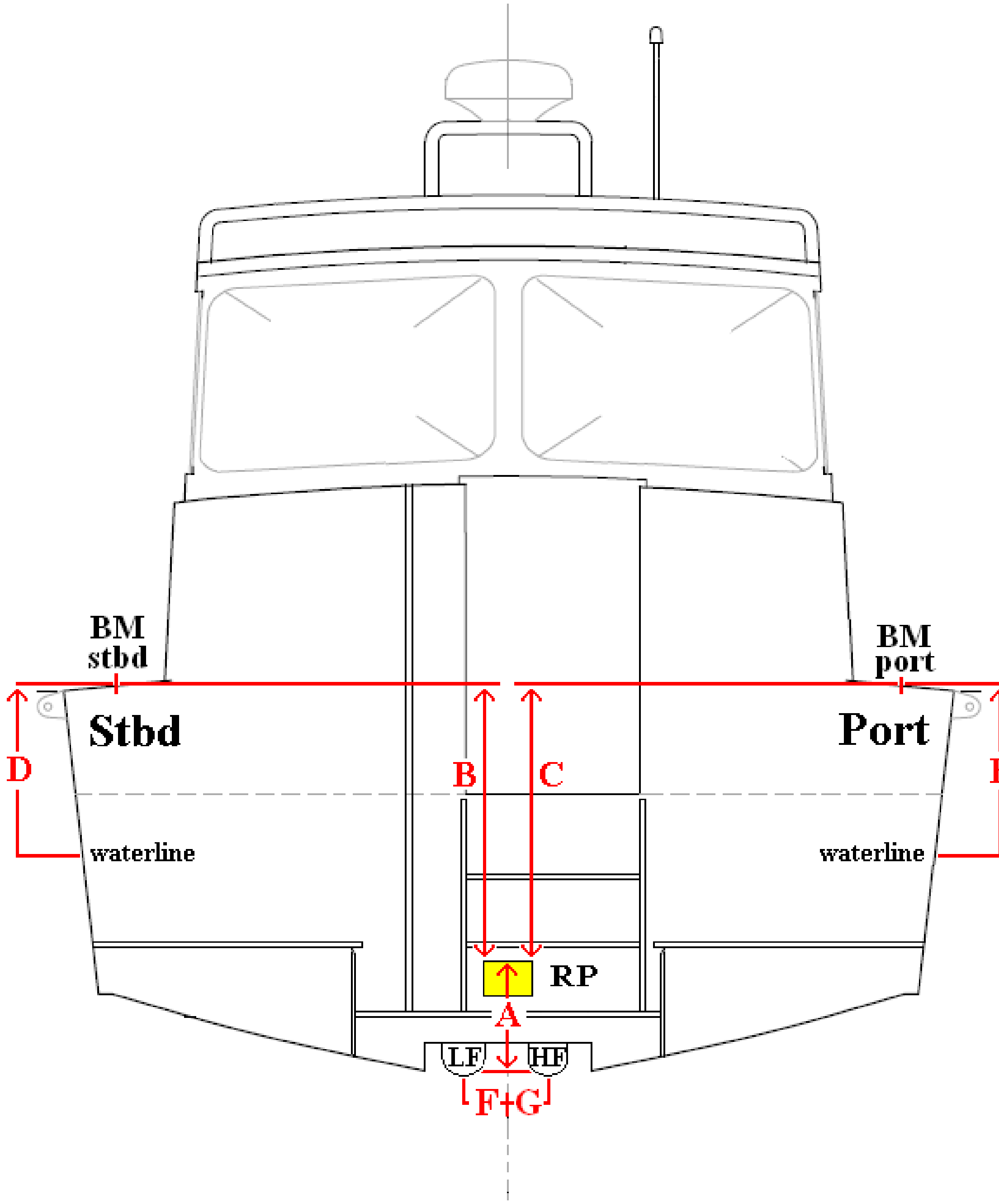



*Figure 3 Athwartship view of 2801 (RA-4) looking aft*

A - The distance from the IMU and the acoustic reference point was taken from the NGS survey and Reson blue prints showing the location.

| 200kHz | 400kHz | |
|---|---|---|
| 0.4775 | 0.4775 | average of distances between the two Plate RMs and the IMU |
| -0.0500 | -0.0310 | corrector from face of Reson transmitter to the reference center |
| 0.4275 | 0.4465 | The distance from sonar head reference center to IMU |

B –The measurement from the IMU to the starboard deck benchmarks was taken directly from the NGS survey. The distance is 1.078m.

C –The measurement from the IMU to the port deck benchmarks was taken directly from the NGS survey. The distance is 1.078m.

D – The distance from the waterline to the deck was determined by measuring directly from the starboard deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.992m (measurement date 05/24/2011).

E – The distance from the waterline to the deck was determined by measuring directly from the port deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.967m (measurement date 05/24/2011).

F – The measurement to the Reson low frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.140m.

G – The measurement to the Reson high frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.156m.

## Waterline determination

| | |
|---|---|
| 1.0780 | Distance from RP to Port side BM |
| -0.9670 | Port side BM to the waterline |
| 0.1110 | Distance from RP to waterline (port side) |

| | |
|---|---|
| 1.0780 | Distance from RP to Starboard side BM |
| -0.9920 | Starboard side BM to the waterline |
| 0.0860 | Distance from RP to waterline (starboard side) |
| 0.0985 | Distance from RP to waterline (average starboard and port sides) |

## Results and Final Error Estimates:

| | | Y (along-ship) | |
|---|---|---|---|
| | | m | date measured |
| RP to center of HF projector | A'-hf | 0.0525 | 5/12/11 |
| RP to center of LF projector | A'-lf | 0.0550 | 5/12/11 |

| | | X (athwartship) m | X date measured | Z (vertical) m | Z date measured |
|---|---|---|---|---|---|
| RP to Reson Ref center LF | A-hf | n/a | n/a | 0.4275 | 5/12/11 |
| RP to Reson Ref center HF | A-lf | n/a | n/a | 0.4465 | 5/12/11 |
| RP to starboard deck BM | B | n/a | n/a | 1.0780 | 4/10/08 |
| RP to port deck BM | C | n/a | n/a | 1.0780 | 4/10/08 |
| Starboard deck BM to waterline | D | n/a | n/a | 0.9920 | 5/24/11 |
| Port deck BM to waterline | E | n/a | n/a | 0.9670 | 5/24/11 |
| Centerline to low freq Reson | F | 0.1400 | 5/10/11 | n/a | n/a |
| Centerline to high freq Reson | G | 0.1560 | 5/10/11 | n/a | n/a |

**CARIS** configuration is based on a Reference Position (RP)
The RP has been defined to coincide with the location of the MRU

| | |
|---|---|
| **X** | athwartship distance [+ starboard] |
| **Y** | along-ship distance [+ towards bow] |
| **Z** | vertical distance [+ into water] |

| | | | |
|---|---|---|---|
| **X** | RP to Reson LF transducer (defined as centerline) | 0.000 | Reson LF |
| | RP to Reson HF transducer (defined as centerline ) | 0.000 | |
| | IMU is RP (mounted centerline) | 0.000 | Reson HF |
| | | | Navigation |
| **Y** | RP to Reson LF transducer (equals A' ) | 0.055 | Gyro |
| | RP to Reson HF transducer (equals A' ) | 0.053 | Heave |
| | IMU is RP | 0.000 | Pitch |
| | | | Roll |
| **Z** | RP to Reson LF transducer (equals A ) | 0.428 | |
| | RP to Reson HF transducer (equals A ) | 0.447 | |
| | IMU is RP | 0.000 | Waterline |
| | RP to waterline (equals B-D) | -0.099 | |

## Recommendations

Due to the combination of the NGS survey and the availability of precise measured blueprints, the offsets of launch 2801 are very precise. Errors in any of the offset measurements should be less than one centimeter. Re-verification measurements of the mounting plate and IMU taken in 2011 were very close to the historic values.

This being disclosed it is the opinion of the hydrographer that the measurements obtained and/or confirmed for this report are an accurate reflection of offset distances of vessel 2801. These offset measurements should be used to create the HVF for the 2011 field season.

# HULL 2802 (RA5) VESSEL OFFSET MEASUREMENTS CERTIFICATION REPORT 2011

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**Vessel**: Hull 2802 (RA5) 28 ft. Aluminum Jensen Survey Launch
**Sonar / Instrument / etc.**: Reson 7125
**Written By:** CST Jacobson, HAST Walsh
**Report Date:** 4/20/11

## Background:

The following report gives a technical description of how vessel 2802 offset measurements were derived so that future surveys may accurately reproduce these results.

During the 2007-2008 winter import, 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 RP (Reference Point) on the POS/MV IMU (Inertial Motion Unit).

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.

## Offset Re-verification Personnel, Location, and Date:

**Personnel**: HAST Walsh, Ens Manda
**Location**: Sand Point, WA
**Date**: 4/12/11

Using reference marks and benchmarks established by the 2008 NGS survey, Rainier personnel were able to re-verify the position of the mounting plate to which the Reson projectors are attached, the IMU, as well as the GPS antennas.

The measured position of the mounting plate and IMU differed by less than 1cm compared to the NGS surveyed position. The measured position of the GPS antennas differed ~1cm compared to the NGS surveyed position. Method of verification utilized steel tapes, plum-bobs, and carpenter squares.

## Waterline Offset Measurement Personnel, Location, and Date:

**Personnel**: ST Wilson, HAST Walsh
**Location**: Sand Point, WA
**Date**: 4/20/11
**Method:** The distance from the waterline to the deck was determined by measuring directly from the deck to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. Both the port and starboard measurements were taken and averaged together for a final value.

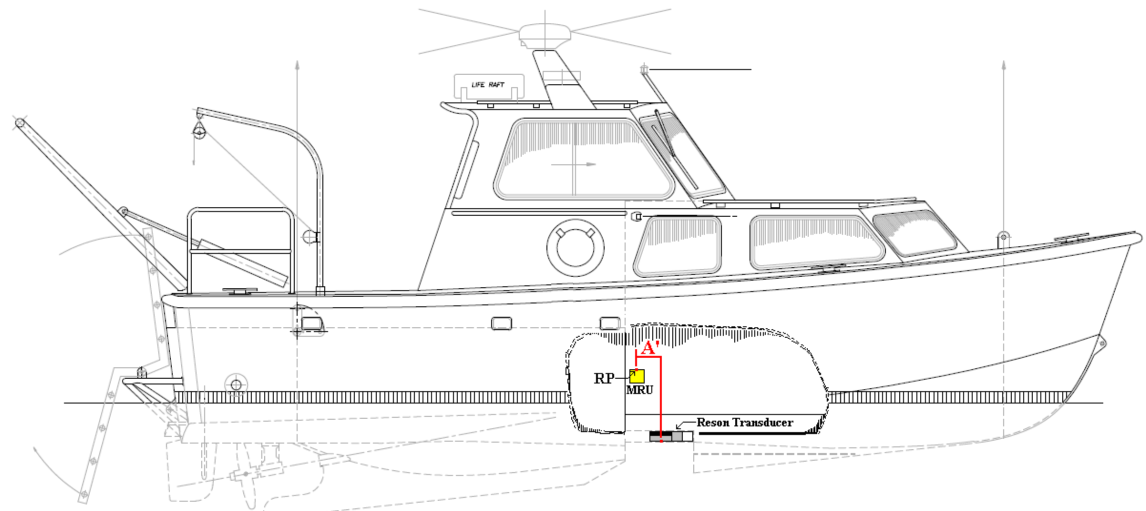


*Figure 1 Side view of 2802 (RA-5)*

A' – The distance from sonar head acoustic center to RP can not be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, or the Reson 7125 manual.

| 200kHz | 400kHz | |
|---|---|---|
| 0.3420 | 0.3420 | average of distances between the two Plate RMs and the IMU |
| -0.0350 | -0.0350 | distance from plate RM to bolt-hole |
| -0.0170 | -0.0170 | bolt-hole to edge of Reson receiver |
| -0.1050 | -0.1050 | thickness of Reson receiver |
| -0.1400 | -0.1425 | distance from the end of Reson projector to the physical center |
| 0.0450 | 0.0425 | distances from sonar reference center to RP. |

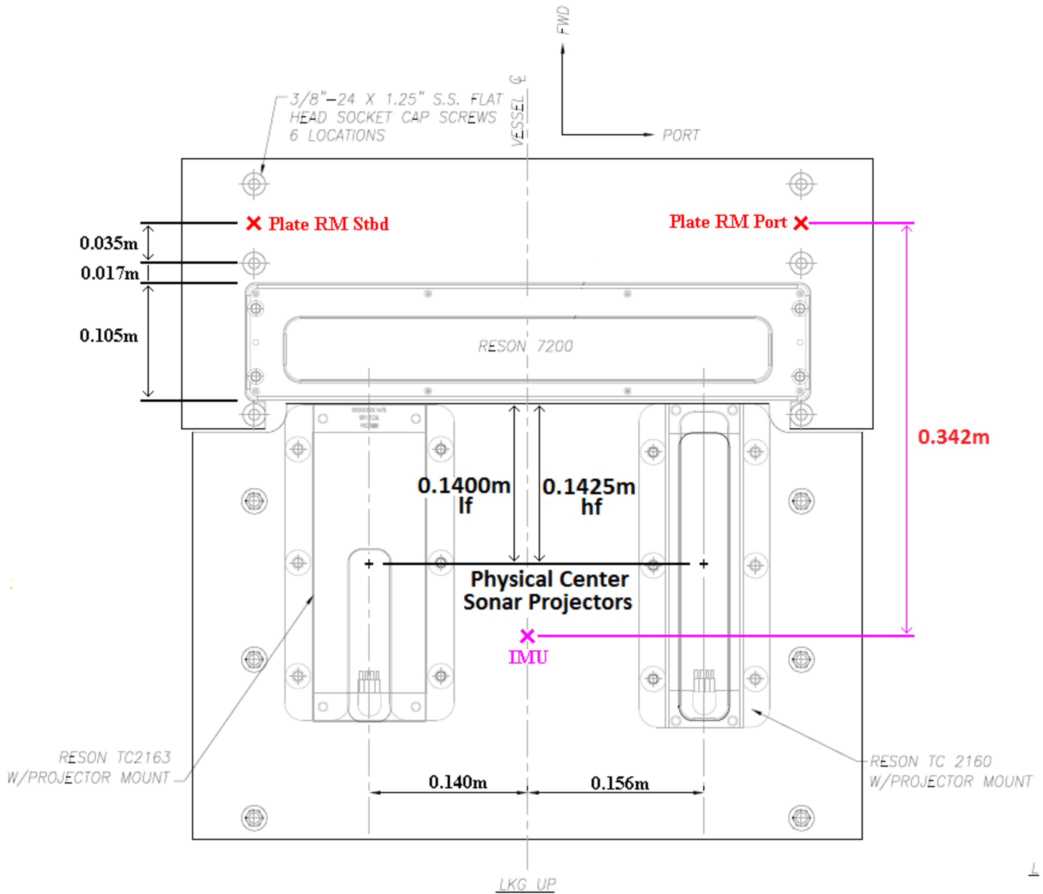


***Figure 2  The Reson 7125 mounting bracket***

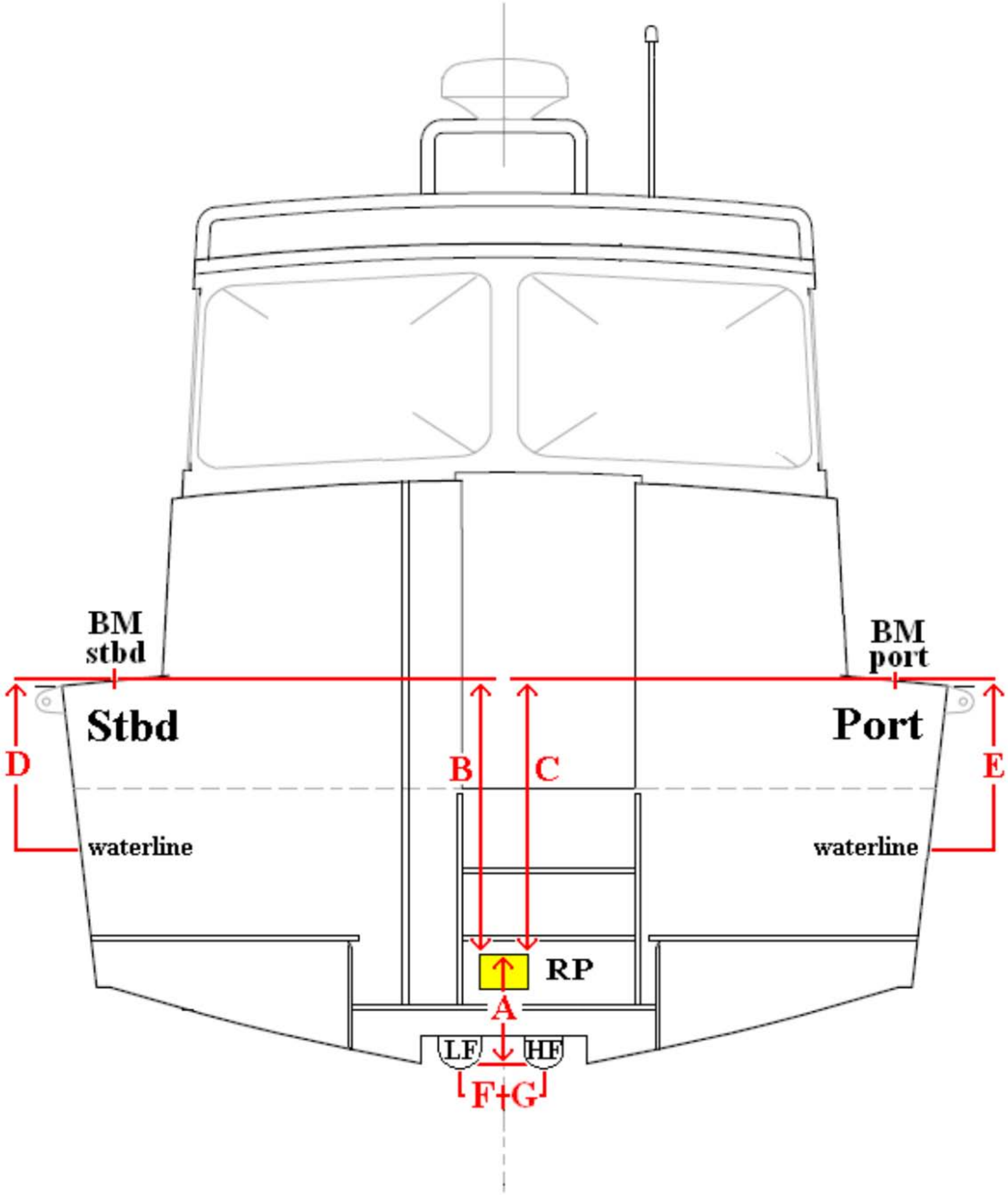


***Figure 3 Athwartship view of 2802 (RA-5) looking aft***

A - The distance from the IMU and the acoustic reference point was taken from the NGS survey and Reson blue prints showing the location.

| 200kHz | 400kHz | |
|---|---|---|
| 0.478 | 0.478 | average of distances between the two Plate RMs and the IMU |
| -0.050 | -0.031 | corrector from face of Reson transmitter to the reference center |
| 0.428 | 0.447 | The distance from sonar head reference center to IMU |

B –The measurement from the IMU to the starboard deck benchmarks was taken directly from the NGS survey. The distance is 1.076m.

C –The measurement from the IMU to the port deck benchmarks was taken directly from the NGS survey. The distance is 1.077m.

D – The distance from the waterline to the deck was determined by measuring directly from the starboard deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 1.002m (measurement date 05/26/2011).

E – The distance from the waterline to the deck was determined by measuring directly from the port deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.973m (measurement date 05/26/2011).

F – The measurement to the Reson low frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.140m.

G – The measurement to the Reson high frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.156m.

## Waterline determination

| | |
|---|---|
| 1.0770 | Distance from RP to Port side BM |
| -0.9730 | Port side BM to the waterline |
| 0.1040 | Distance from RP to waterline (port side) |

| | |
|---|---|
| 1.0760 | Distance from RP to Starboard side BM |
| -1.0020 | Starboard side BM to the waterline |
| 0.0740 | Distance from RP to waterline (starboard side) |
| 0.0890 | Distance from RP to waterline (average starboard and port sides) |

## Results and Final Error Estimates:

| | | Y (along-ship) | |
|---|---|---|---|
| | | cm. | date measured |
| RP to center of HF projector | A'-hf | 0.0425 | 5/12/11 |
| RP to center of LF projector | A'-lf | 0.0450 | 5/12/11 |

| | | X (athwartship) | | Z (vertical) | |
|---|---|---|---|---|---|
| | | cm. | date measured | cm. | date measured |
| RP to Reson Ref center LF | A-hf | n/a | n/a | 0.4280 | 5/12/11 |
| RP to Reson Ref center HF | A-lf | n/a | n/a | 0.4470 | 5/12/11 |
| RP to starboard deck BM | B | n/a | n/a | 1.0760 | 4/10/08 |
| RP to port deck BM | C | n/a | n/a | 1.0770 | 4/10/08 |
| Starboard deck BM to waterline | D | n/a | n/a | 1.0020 | 5/26/11 |
| Port deck BM to waterline | E | n/a | n/a | 0.9730 | 5/26/11 |
| Centerline to low freq Reson | F | 0.1400 | 4/10/08 | n/a | n/a |
| Centerline to high freq Reson | G | 0.1560 | 4/10/08 | n/a | n/a |

**CARIS** configuration is based on a Reference Position (RP)
The RP has been defined to coincide with the location of the MRU

| | |
|---|---|
| **X** | athwartship distance [+ starboard] |
| **Y** | along-ship distance [+ towards bow] |
| **Z** | vertical distance [+ into water] |

| | | | |
|---|---|---|---|
| **X** | RP to Reson LF transducer (Defined as centerline ) | 0.000 | Reson LF |
| | RP to Reson HF transducer (Defined as centerline ) | 0.000 | |
| | IMU is RP (mounted centerline) | 0.000 | Reson HF |
| | | | Navigation |
| **Y** | RP to Reson LF transducer (equals C' ) | 0.045 | Gyro |
| | RP to Reson HF transducer (equals C' ) | 0.043 | Heave |
| | IMU is RP | 0.000 | Pitch |
| | | | Roll |
| **Z** | RP to Reson LF transducer (equals A ) | 0.428 | |
| | RP to Reson HF transducer (equals A ) | 0.447 | |
| | IMU is RP | 0.000 | |
| | RP to waterline (equals B-D) | -0.089 | Waterline |

## Recommendations

Due to the combination of the NGS survey and the availability of precise measured blueprints, the offsets of launch 2801 are very precise. Errors in any of the offset measurements should be less than one centimeter. Re-verification measurements of the mounting plate and IMU taken in 2011 were very close to the historic values.

This being disclosed it is the opinion of the hydrographer that the measurements obtained and/or confirmed for this report are an accurate reflection of offset distances of vessel 2801. These offset measurements should be used to create the HVF for the 2011 field season.

# HULL 2803 (RA3) VESSEL OFFSET MEASUREMENTS CERTIFICATION REPORT 2011

**Vessel**: Hull 2803 (RA3) 28 ft. Aluminum Jensen Survey Launch
**Sonar / Instrument / etc.**: Reson 7125
**Written By:** CST Jacobson, HAST Walsh
**Report Date:** 5/20/11

## Background:

The following report gives a technical description of how vessel 2803 offset measurements were derived so that future surveys may accurately reproduce these results.

During the 2008-2009 winter import 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 RP (Reference Point) on the POS/MV IMU (Inertial Motion Unit).

At the time NGS personnel were present for the launch survey, the projector mounting plate was not yet installed in its final position. Two benchmarks positioned by NGS personnel by placing punch-marks on the keel (one fore and one aft of the mounting plate). By using these two benchmarks, the position of the projector mounting plate was easily measured by *Rainier* personnel once the plate was installed in its final position. Since the sonar mounting bracket was built to precise dimensional standards, the exact orientation of the Reson 7125 sonar projectors could easily be determined.

## Offset Re-verification Personnel, Location, and Date:

**Personnel**: HAST Walsh, Ens Manda
**Location**: Sand Point, WA
**Date**: 4/12/11

Using reference marks and benchmarks established by the 2008 NGS survey, Rainier personnel were able to re-verify the position of the mounting plate to which the Reson projectors are attached, the IMU, as well as the GPS antennas.

The measured position of the mounting plate and IMU differed by less than 1cm compared to the NGS surveyed position. The measured position of the GPS antennas differed ~1cm compared to the NGS surveyed position. Method of verification utilized steel tapes, plum-bobs, and carpenter squares.

## Waterline Offset Measurement Personnel, Location, and Date:

**Personnel**: HAST Walsh, HAST Bowker
**Location**: Sand Point, WA
**Date**: 5/24/11
**Method**: The distance from the waterline to the deck was determined by measuring directly from the deck to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. Both the port and starboard measurements were taken and averaged together for a final value.

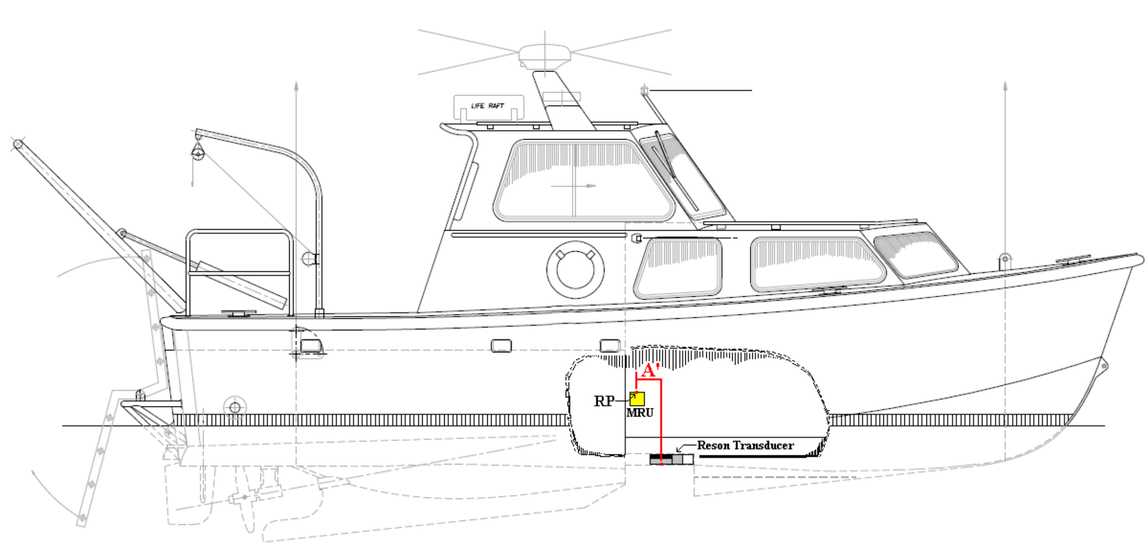


***Figure 1.** Side view of 2803 (RA-3)*

A' – The distance from the IMU to the sonar Reference point can not be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, steel tape readings, or the Reson 7125 manual.

| 200khz | 400khz | |
|---|---|---|
| 0.4200 | 0.4200 | distance between fore keel BM and the IMU |
| -0.0340 | -0.0340 | distance from fore keel BM to forward edge of flow plate assembly |
| -0.1092 | -0.1092 | forward edge of flow plate assembly to edge of Reson receiver |
| -0.1050 | -0.1050 | thickness of Reson receiver |
| -0.1400 | -0.1425 | edge of Reson receiver to Reson transmitter reference center |
| 0.03180 | 0.0293 | The distance from IMU to sonar Reference Point |

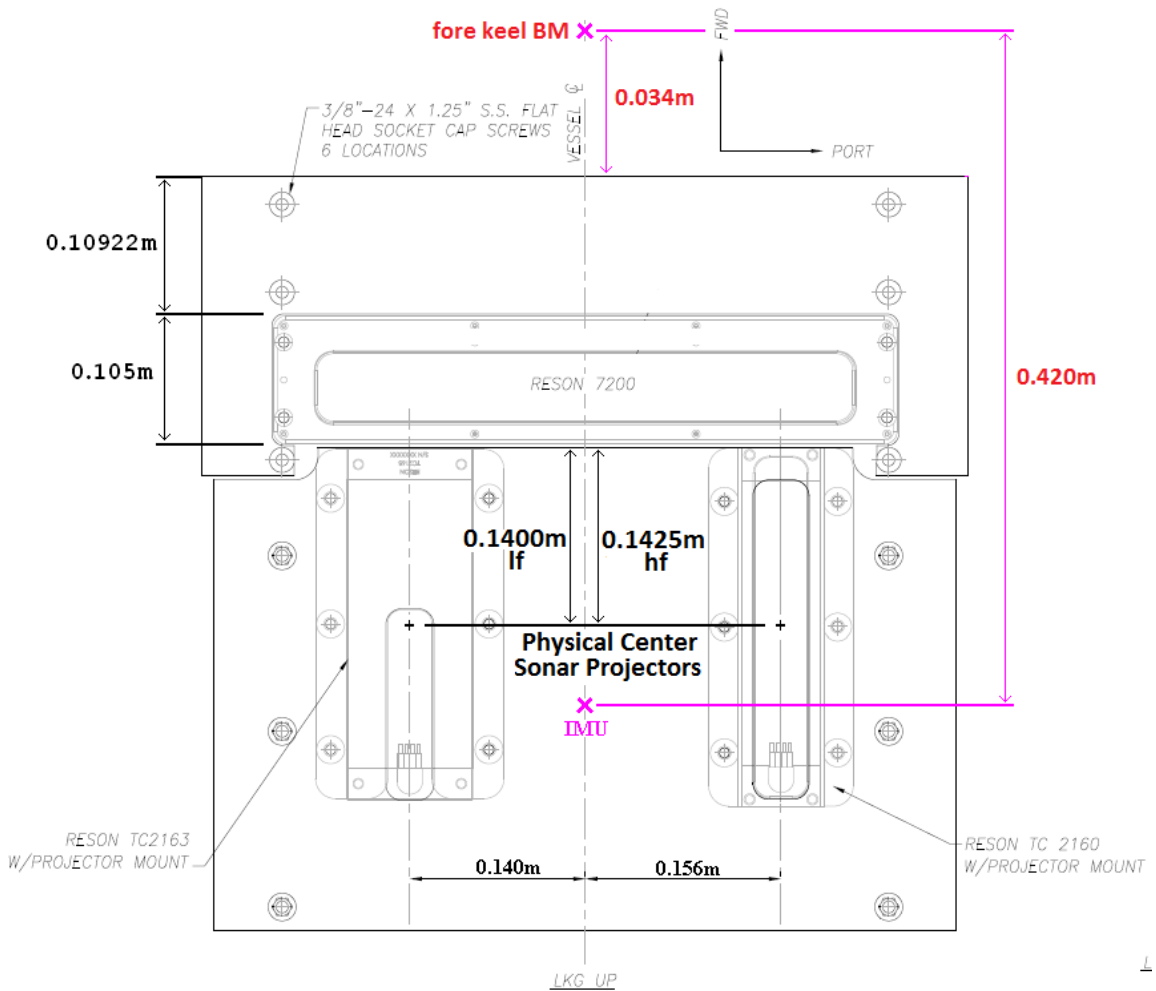


***Figure 2 The Reson 7125 mounting bracket***

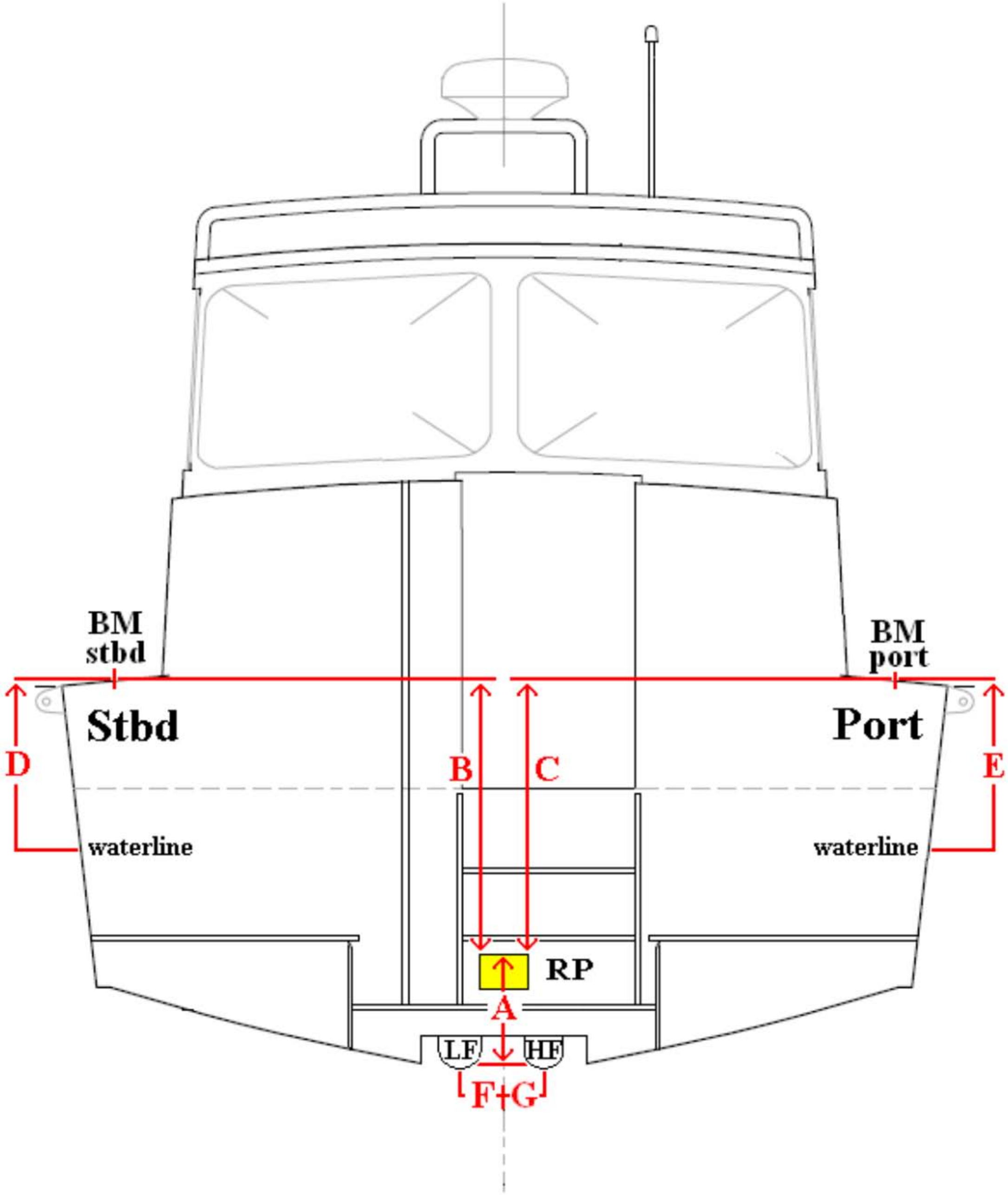


*Figure 3 Athwartship view of 2803 (RA-3) looking aft*

A - The distance from sonar head acoustic center to RP can not be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, steel tape readings, or the Reson 7125 manual.

| 200kHz | 400kHz | |
|---|---|---|
| 0.619 | 0.619 | distance between fore keel BM and the IMU |
| -0.140 | -0.140 | distance from fore keel BM to the flow plate assembly |
| -0.050 | -0.031 | corrector from face of Reson transmitter to the acoustic center |
| 0.429 | 0.448 | The distance from sonar head reference center to IMU |

B –The measurement from the IMU to the starboard deck benchmarks was taken directly from the NGS survey. The distance is 1.059m.

C –The measurement from the IMU to the port deck benchmarks was taken directly from the NGS survey. The distance is 1.074m.

D – The distance from the waterline to the deck was determined by measuring directly from the starboard deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.975m (measurement date 05/24/2011).

E – The distance from the waterline to the deck was determined by measuring directly from the port deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.994m (measurement date 05/24/2011).

F – The measurement to the Reson low frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.140m.

G – The measurement to the Reson high frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.156m.

## Waterline determination

| | |
|---|---|
| 1.0740 | Distance from RP to Port side BM |
| -0.9940 | Port side BM to the waterline |
| 0.0800 | Distance from RP to waterline (port side) |

| | |
|---|---|
| 1.0590 | Distance from RP to Starboard side BM |
| -0.9750 | Starboard side BM to the waterline |
| 0.0840 | Distance from RP to waterline (starboard side) |
| | |
| 0.0820 | Distance from RP to waterline (average starboard and port sides) |

## Results and Final Error Estimates:

| | | Y (along-ship) | |
|---|---|---|---|
| | | m | date measured |
| RP to center of HF projector | C'-hf | 0.0293 | 5/12/11 |
| RP to center of LF projector | C'-lf | 0.0318 | 5/12/11 |

| | | X (athwartship) m | X (athwartship) date measured | Z (vertical) m | Z (vertical) date measured |
|---|---|---|---|---|---|
| RP to Reson Ref center LF | A-hf | n/a | n/a | 0.4290 | 5/12/11 |
| RP to Reson Ref center HF | A-lf | n/a | n/a | 0.4480 | 5/12/11 |
| RP to starboard deck BM | B | n/a | n/a | 1.0590 | 4/7/09 |
| RP to port deck BM | C | n/a | n/a | 1.0740 | 4/7/09 |
| Starboard deck BM to waterline | D | n/a | n/a | 0.9750 | 5/24/11 |
| Port deck BM to waterline | E | n/a | n/a | 0.9940 | 5/24/11 |
| Centerline to low freq Reson | F | 0.1400 | 4/7/09 | n/a | n/a |
| Centerline to high freq Reson | G | 0.1560 | 4/7/09 | n/a | n/a |

**CARIS** configuration is based on a Reference Position (RP)
The RP has been defined to coincide with the location of the MRU

| | |
|---|---|
| **X** | athwartship distance [+ starboard] |
| **Y** | along-ship distance [+ towards bow] |
| **Z** | vertical distance [+ into water] |

| | | | |
|---|---|---|---|
| **X** | RP to Reson LF transducer (Defined as centerline ) | 0.000 | Reson LF |
| | RP to Reson HF transducer (Defined as centerline) | 0.000 | |
| | IMU is RP (mounted centerline) | 0.000 | Reson HF |
| | | | Navigation |
| **Y** | RP to Reson LF transducer (equals C' ) | 0.032 | Gyro |
| | RP to Reson HF transducer (equals C' ) | 0.029 | Heave |
| | IMU is RP | 0.000 | Pitch |
| | | | Roll |
| **Z** | RP to Reson LF transducer (equals A ) | 0.429 | |
| | RP to Reson HF transducer (equals A ) | 0.448 | |
| | IMU is RP | 0.000 | |
| | RP to waterline (equals average of B-D and C-E) | -0.082 | Waterline |

## Recommendations

Due to the combination of the NGS survey and the availability of precise measured blueprints, the offsets of launch 2803 are very precise. Errors in any of the offset measurements should be less than one centimeter.

It is the opinion of the hydrographer that the measurements obtained and/or confirmed for this report are an accurate reflection of offset distances of vessel 2803. These offset measurements should be used to create the HVF for the 2011 field season.

# HULL 2803 (RA3) VESSEL OFFSET MEASUREMENTS CERTIFICATION REPORT 2011
# Reson Seabat 8125 sonar

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**Vessel**: Hull 2803 (RA3) 28 ft. Aluminum Jensen Survey Launch
**Sonar / Instrument / etc.**: Reson 8125
**Written By:** CST Jacobson
**Report Date:** 9/19/2011

## Background:

The following report gives a technical description of how vessel 2803 offset measurements for the tilt-mounted Reson 8125 were derived so that future surveys may accurately reproduce these results. The spatial relationship of various sensors and reference points are determined in relation to the RP (Reference Point) on the POS/MV IMU (Inertial Motion Unit).

The Reson SeaBat 8125 is hull-mounted on vessel 2803 with a 34° angle looking towards starboard. The transducer is attached with a custom made aluminum bracket bolted to the forward hull hardpoint on the starboard side. This tilted configuration of the RESON 8125 transducer enables the collection of near-shore SWMB while driving a safe distance offshore.

## Calibration Location, Date, and Personnel:

**Personnel**: CST Jacobson, ST Walsh, AST Bowker
**Coxwain**: N/A
**Location**: Lake Union drydock, WA & underway, Inside Passage (Canada)
**Date**: 9/19/11
**Status**: Measurements were derived using direct measurements by Rainier personnel, the NGS survey and technical schematics from the Reson 8125 manual.

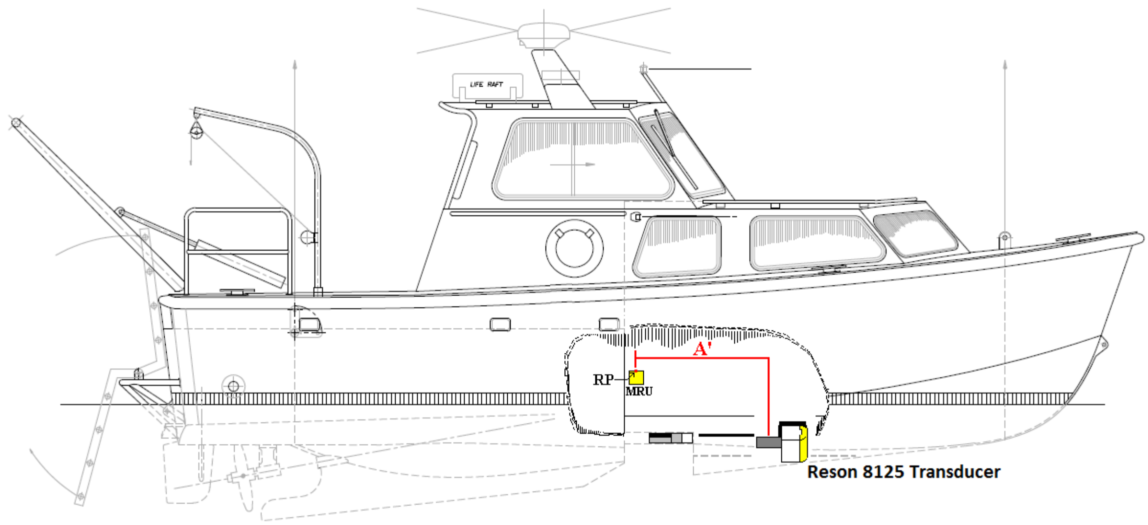


***Figure 1 Along-ship view of vessel 2803 (RA-3)***

A'– The distance from sonar head acoustic center to RP was not be directly measured, but instead derived by manipulating several independent measurements. The IMU to the Fore keel benchmark distance was taken directly from the NGS survey while the distance from the edge of Reson projector to Reson acoustic center was taken from the Reson 8125 manual. The distance from the Fore keel benchmark to aft edge of Reson projector was directly measured by Rainier personnel with a steel tape.

| | |
|---|---|
| 0.420 | distance from IMU to the Fore keel benchmark |
| 0.386 | distance from Fore keel benchmark to aft edge of Reson projector |
| 0.120 | aft edge of Reson projector to Reson acoustic center |
| 0.926 | The distance from sonar head acoustic center to RP |

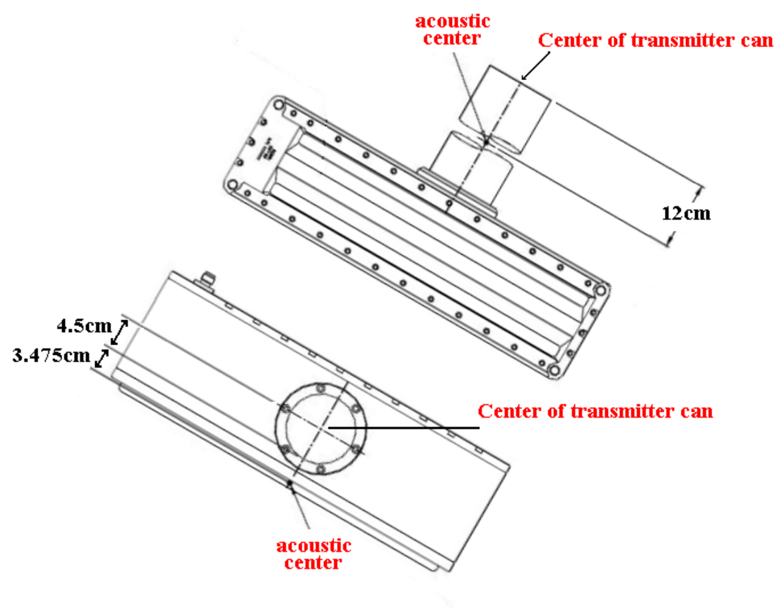


***Figure 2 Acoustic center of the 8125 transducer***

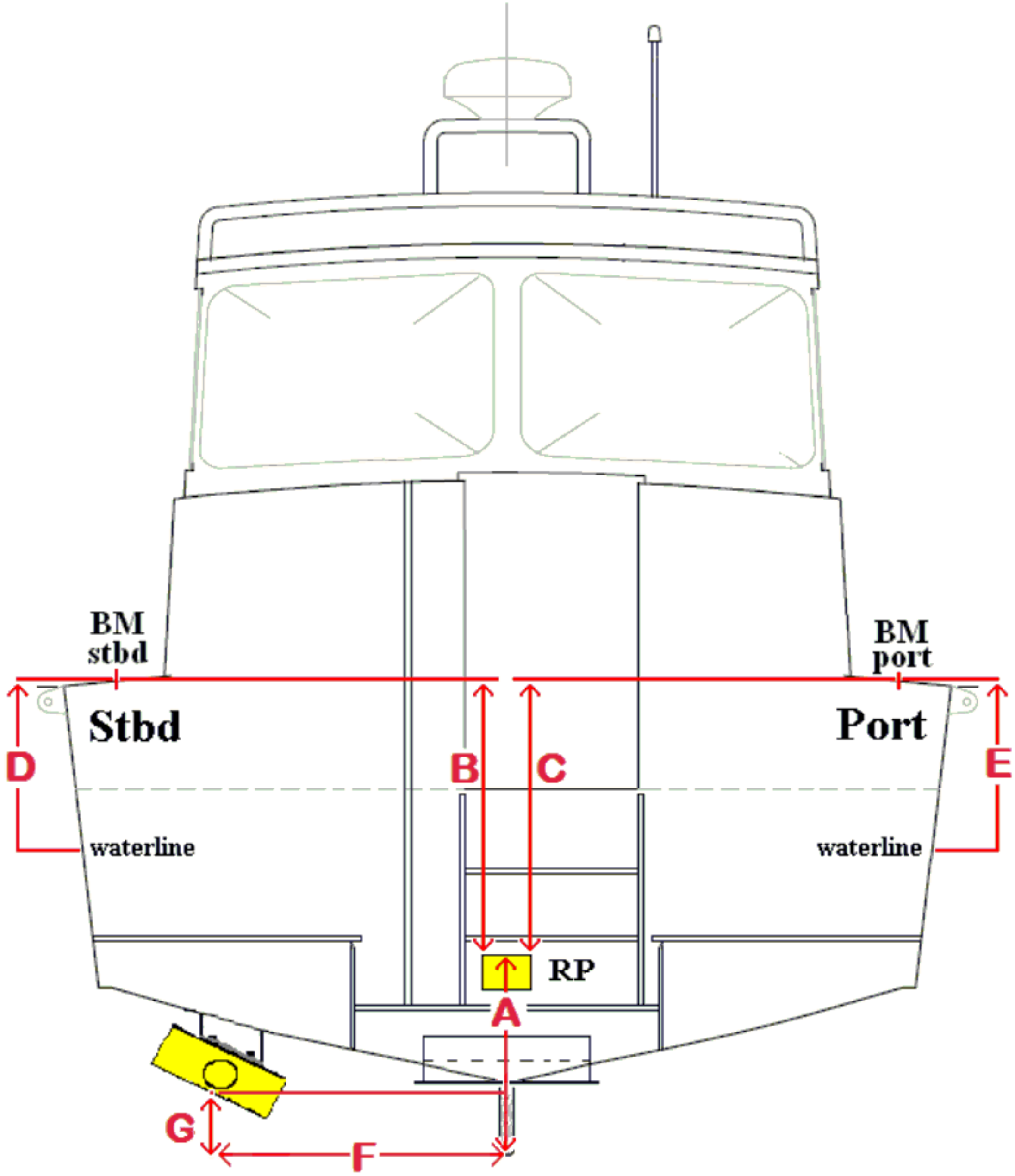


***Figure 3 Athwartship view of 2803 (RA-3) looking aft***

A – The distance from the IMU to the Fore keel benchmark was taken directly from the NGS survey. The distance is 0.619m.

B –The measurement from the IMU to the starboard deck benchmarks was taken directly from the NGS survey. The distance is 1.059m.

C –The measurement from the IMU to the port deck benchmarks was taken directly from the NGS survey. The distance is 1.074m.

D – The distance from the waterline to the deck was determined by measuring directly from the starboard deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.975m (measurement date 05/24/2011).

E – The distance from the waterline to the deck was determined by measuring directly from the port deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.994m (measurement date 05/24/2011).

F – The distance from sonar head acoustic center to RP was derived from a direct measurement with a steel tape to the keel. Assuming that the keel is centerline as is the IMU, these distances should be equal.

| | |
|---|---|
| 0.733 | Distance from IMU to the acoustic center |

G – The distance from sonar head acoustic center to the Fore keel benchmark distance was directly measured by Rainier personnel with a steel tape. The distance is 0.046m.

| | |
|---|---|
| 0.619 | The distance from the IMU to the Fore keel benchmark |
| -0.046 | Distance from fore keel benchmark to the Reson acoustic center |
| 0.573 | The distance from sonar head acoustic center to RP |

## Results and Final Error Estimates:

| | | Y (along-ship) | |
|---|---|---|---|
| | | m | date measured |
| RP to acoustic center of Reson | A' | 0.9260 | 9/19/11 |

| | | X (athwartship) | | Z (vertical) | |
|---|---|---|---|---|---|
| | | m | date measured | m | date measured |
| RP to Keel BM | A | n/a | n/a | 0.619 | 4/7/09 |
| RP to starboard deck BM | B | n/a | n/a | 1.059 | 4/7/09 |
| RP to port deck BM | C | n/a | n/a | 1.074 | 4/7/09 |
| Starboard deck BM to waterline | D | n/a | n/a | 0.975 | 5/24/11 |
| Port deck BM to waterline | E | n/a | n/a | 0.994 | 5/24/11 |
| Keel BM to Reson acoustic cente | G | n/a | n/a | 0.046 | 9/19/11 |
| C/L to Reson acoustic center | F | 0.733 | 9/19/09 | n/a | n/a |

**CARIS** configuration is based on a Reference Position (RP)
The RP has been defined to coincide with the location of the MRU

| | |
|---|---|
| **X** | athwartship distance [+ starboard] |
| **Y** | along-ship distance [+ towards bow] |
| **Z** | vertical distance [+ into water] |

| | | | |
|---|---|---|---|
| **X** | RP to Reson acoustic center | 0.733 | Reson |
| | IMU is RP (mounted centerline) | 0.000 | |
| | | | Navigation |
| | | | Gyro |
| | | | Heave |
| **Y** | RP to Reson acoustic center | 0.926 | Pitch |
| | IMU is RP | 0.000 | Roll |
| **Z** | RP to Reson acoustic center | 0.573 | |
| | IMU is RP | 0.000 | |
| | RP to waterline (equals average of B-D and C-E) | -0.082 | Waterline |

## Recommendations

Due to the availability of the NGS surveyed benchmark, single direct measurements to the Reson transducer could be made by Rainier personnel. With these measurements, and the availability of precise measured schematics from the Reson manual, the offsets of launch 2803 are fairly precise. Errors in any of the offset measurements should be within one centimeter.

This being disclosed, it is the opinion of the hydrographer that the measurements obtained and/or confirmed for this report are an accurate reflection of offset distances of vessel 2803. These offset measurements should be used to create the HVF for the 2011 field season.

# HULL 2804 (RA6) VESSEL OFFSET MEASUREMENTS CERTIFICATION REPORT 2011

**Vessel**: Hull 2804 (RA6) 28 ft. Aluminum Jensen Survey Launch
**Sonar / Instrument / etc.**: Reson 7125
**Written By:** CST Jacobson, HAST Walsh
**Report Date:** 5/21/11

## Background:

The following report gives a technical description of how vessel 2804 offset measurements were derived so that future surveys may accurately reproduce these results.

During the 2008-2009 winter import 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 RP (Reference Point) on the POS/MV IMU (Inertial Motion Unit).

At the time NGS personnel were present for the launch survey, the projector mounting plate was not yet installed in its final position. Two benchmarks positioned by NGS personnel by placing punch-marks on the keel (one fore and one aft of the mounting plate). By using these two benchmarks, the position of the projector mounting plate was easily measured by *Rainier* personnel once the plate was installed in its final position. Since the sonar mounting bracket was built to precise dimensional standards, the exact orientation of the Reson 7125 sonar projectors could easily be determined.

## Offset Re-verification Personnel, Location, and Date:

**Personnel**: HAST Walsh, HAST Bowker, HAST Doroba, HAST Geiger
**Location**: Sand Point, WA
**Date**: 5/12/11

Using reference marks and benchmarks established by the 2008 NGS survey, *Rainier* personnel were able to re-verify the position of the mounting plate to which the Reson projectors are attached, the IMU, as well as the GPS antennas.

The measured position of the mounting plate and IMU differed by less than 1cm compared to the NGS surveyed position. The measured position of the GPS antennas differed ~1cm compared to the NGS surveyed position. Method of verification utilized steel tapes, plum-bobs, and carpenter squares, consulting both the NGS survey and blueprints of the sonar mounting bracket.

## Waterline Offset Measurement Personnel, Location, and Date:

**Personnel**: ST Wilson, HAST Walsh
**Location**: Sand Point, WA
**Date**: 4/20/11

**Method**: The distance from the waterline to the deck was determined by measuring directly from the deck to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. Both the port and starboard measurements were taken and averaged together for a final value.

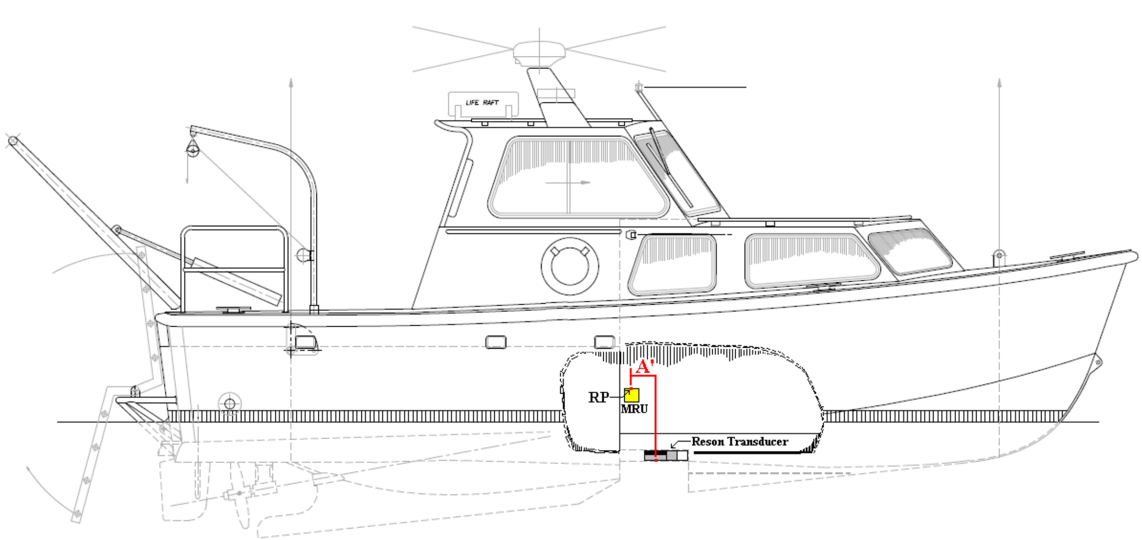


***Figure 1 Side view of 2804 (RA-6)***

A' – The distance from sonar head acoustic center to RP can not be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, steel tape readings, or the Reson 7125 manual.

| 200Khz | 400Khz | |
|---|---|---|
| 0.413 | 0.413 | distance between fore keel BM and the IMU |
| -0.0280 | -0.0280 | distance from fore keel BM to forward edge of flow plate assembly |
| -0.1092 | -0.1092 | forward edge of flow plate assembly to edge of Reson receiver |
| -0.1050 | -0.1050 | thickness of Reson receiver |
| -0.1400 | -0.1425 | edge of Reson receiver to Reson transmitter reference center |
| 0.0308 | 0.0283 | The distance from sonar head reference center to RP |

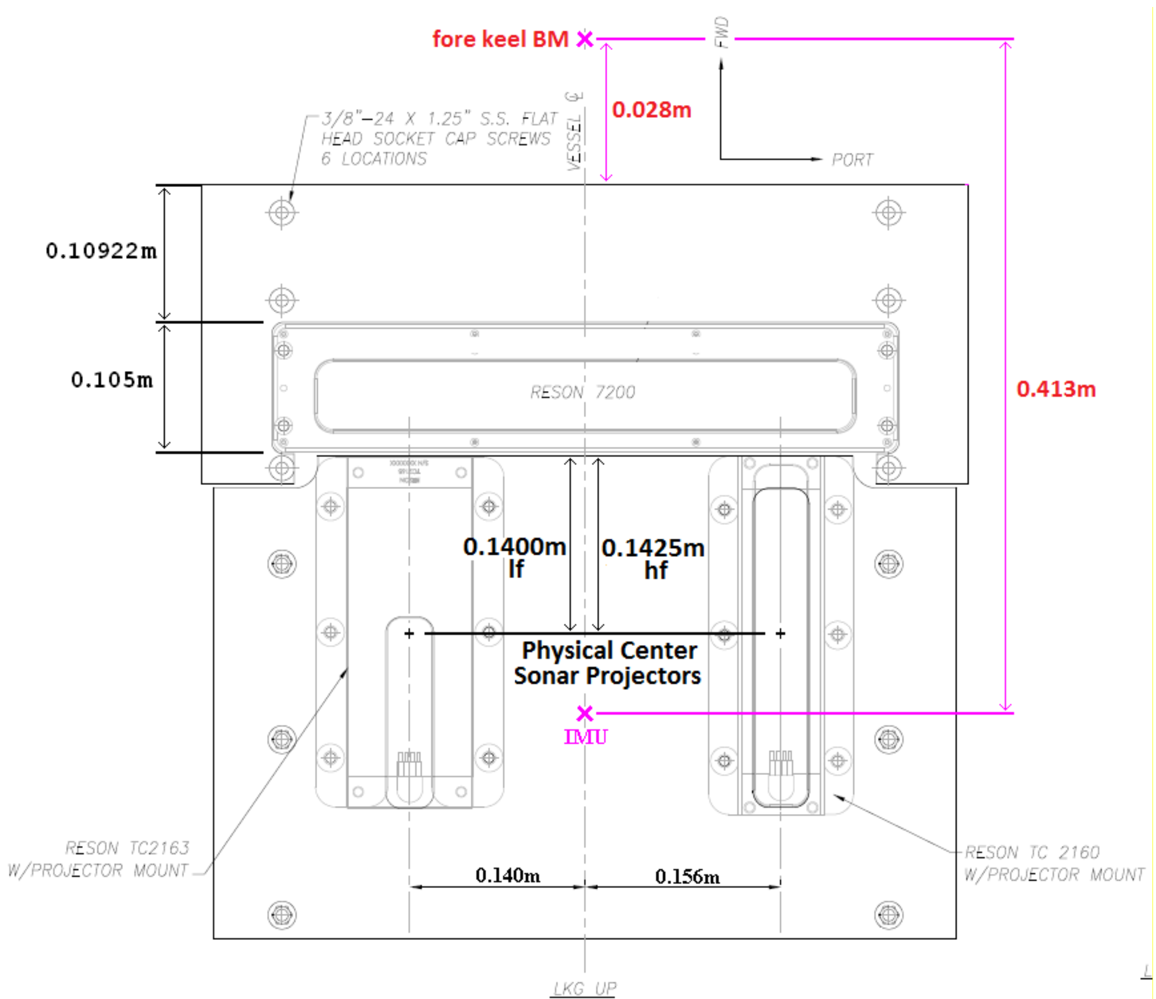


*Figure 2. The Reson 7125 mounting bracket*

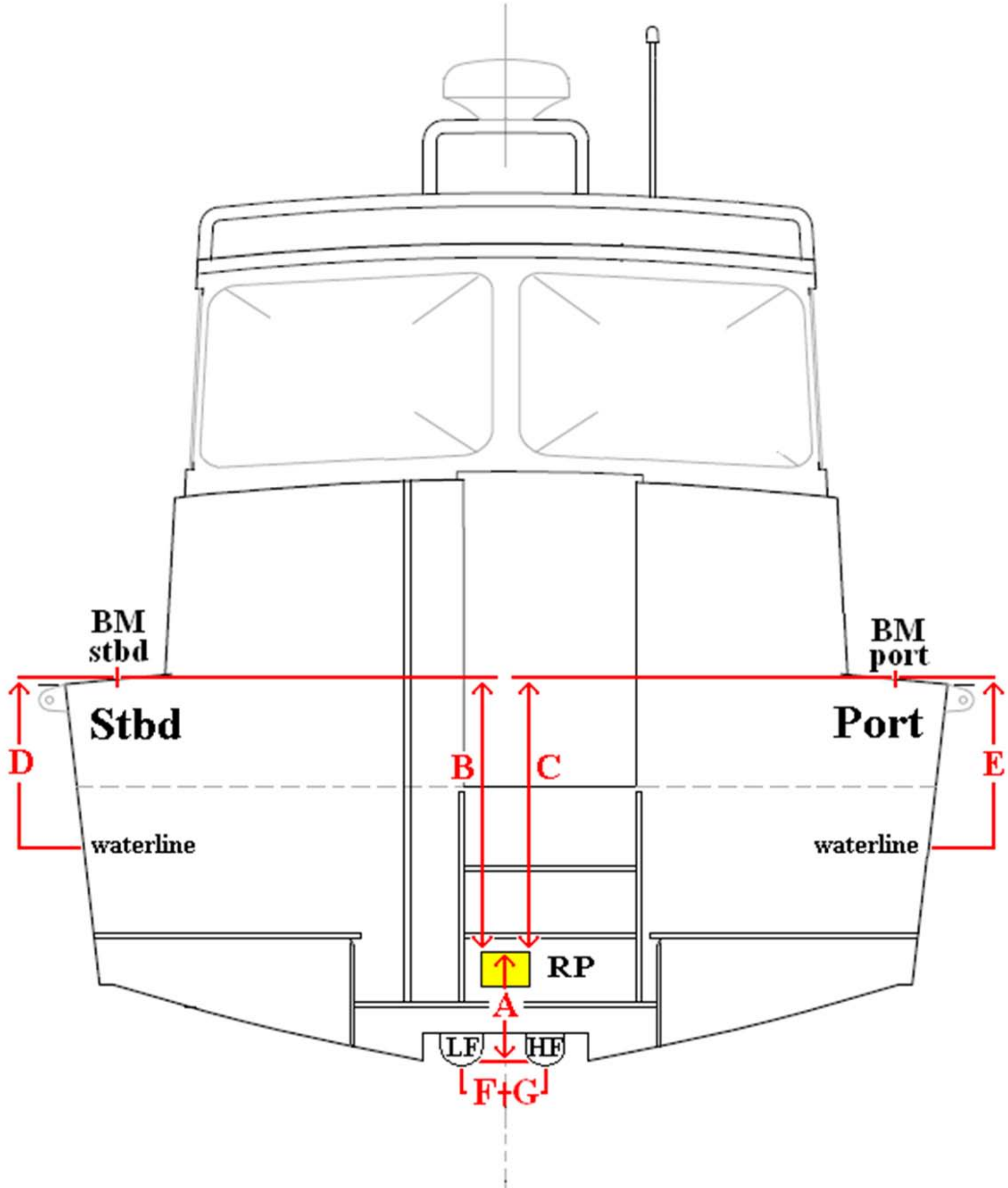


***Figure 3 Athwartship view of 2804 (RA-6) looking aft***

A - The distance from sonar head acoustic center to RP can not be directly measured, but instead must be derived by manipulating several independent measurements. All of these dimensions (See fig. 2) were taken directly from the NGS survey, the mounting plate blueprints, steel tape readings, or the Reson 7125 manual.

| 200Khz | 400Khz | |
|---|---|---|
| 0.613 | 0.613 | distance between fore keel BM and the IMU |
| -0.143 | -0.143 | distance from fore keel BM to the flow plate assembly |
| -0.050 | -0.031 | corrector from face of Reson transmitter to the reference center |
| 0.420 | 0.439 | The distance from sonar head reference center to IMU |

B –The measurement from the IMU to the starboard deck benchmarks was taken directly from the NGS survey. The distance is 1.059m.

C –The measurement from the IMU to the port deck benchmarks was taken directly from the NGS survey. The distance is 1.078m.

D – The distance from the waterline to the deck was determined by measuring directly from the starboard deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 0.992m.

E – The distance from the waterline to the deck was determined by measuring directly from the port deck BM to the waterline while the launch was in the water. A carpenter level was held level to the deck while a steel tape was used to measure directly to the surface of the water. The distance is 1.008m.

F – The measurement to the Reson low frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.140m.

G – The measurement to the Reson high frequency transmitter acoustic center was obtained directly from the mounting plate blueprints, 0.156m.

## Waterline determination

| | |
|---|---|
| 1.0780 | Distance from RP to Port side BM |
| -1.0080 | Port side BM to the waterline |
| 0.0700 | Distance from RP to waterline (port side) |

| | |
|---|---|
| 1.0590 | Distance from RP to Starboard side BM |
| -0.9920 | Starboard side BM to the waterline |
| 0.0670 | Distance from RP to waterline (starboard side) |
| | |
| 0.0685 | Distance from RP to waterline (average starboard and port sides) |

## Results and Final Error Estimates:

| | | Y (along-ship) | |
|---|---|---|---|
| | | m | date measured |
| RP to center of HF projector | A'-hf | 0.028 | 5/12/11 |
| RP to center of LF projector | A'-lf | 0.031 | 5/12/11 |

| | | X (athwartship) | | Z (vertical) | |
|---|---|---|---|---|---|
| | | m | date measured | m | date measured |
| RP to Reson Ref center LF | A-hf | n/a | n/a | 0.420 | 5/10/11 |
| RP to Reson Ref center HF | A-lf | n/a | n/a | 0.439 | 5/10/11 |
| RP to starboard deck BM | B | n/a | n/a | 1.059 | 4/20/11 |
| RP to port deck BM | C | n/a | n/a | 1.078 | 4/20/11 |
| Starboard deck BM to waterline | D | n/a | n/a | 0.992 | 4/20/11 |
| Port deck BM to waterline | E | n/a | n/a | 1.008 | 4/20/11 |
| Centerline to low freq Reson | F | 0.140 | 4/9/11 | n/a | n/a |
| Centerline to high freq Reson | G | 0.156 | 4/9/11 | n/a | n/a |

**CARIS** configuration is based on a Reference Position (RP)
The RP has been defined to coincide with the location of the MRU

| | |
|---|---|
| **X** | athwartship distance [+ starboard] |
| **Y** | along-ship distance [+ towards bow] |
| **Z** | vertical distance [+ into water] |

| | | | |
|---|---|---|---|
| **X** | RP to Reson LF transducer (defined as centerline ) | 0.000 | Reson LF |
| | RP to Reson HF transducer (defined as centerline ) | 0.000 | |
| | IMU is RP (mounted centerline) | 0.000 | Reson HF |
| | | | Navigation |
| **Y** | RP to Reson LF transducer (equals A' ) | 0.031 | Gyro |
| | RP to Reson HF transducer (equals A' ) | 0.028 | Heave |
| | IMU is RP | 0.000 | Pitch |
| | | | Roll |
| **Z** | RP to Reson LF transducer (equals A ) | 0.420 | |
| | RP to Reson HF transducer (equals A ) | 0.439 | |
| | IMU is RP | 0.000 | |
| | RP to waterline (equals average of B-D and C-E) | -0.069 | Waterline |

# Recommendations

Due to the combination of the NGS survey and the availability of precise measured blueprints, the offsets of launch 2804 are very precise. Errors in any of the offset measurements should be less than one centimeter. Re-verification measurements of the mounting plate and IMU taken in 2011 were very close to the historic values.

It is the opinion of the hydrographer that the measurements obtained and/or confirmed for this report are an accurate reflection of offset distances of vessel 2804. These offset measurements should be used to create the HVF for the 2011 field season.

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**INSTRUMENTATION & METHODOLOGIES BRANCH**

# RANIER LAUNCHES 1101, 2801 & 2802
# SPATIAL RELATIONSHIP SURVEYS
# FIELD REPORT

**Kendall L. Fancher**
**March 31, 2008**

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

## PURPOSE

The primary purpose of the survey was to accurately determine the spatial relationship of various sensors, and the components of POS MV navigation systems aboard NOAA survey launches 1101, 2801 and 2802.

## PROJECT DETAILS

This survey was conducted in Seattle, WA on the 25th, 26th and 27th of March, 2008. The weather was cool and overcast with steady rain during the afternoon of the 25th. The vessels were hauled out of the water and placed onto jacks to conduct this survey. The launches were reported to have been leveled relative to the top of their respective IMU housings, prior to the survey.

## INSTRUMENTATION

The Leica (Wild) TC2003 precision total station was used to make all measurements.

Technical Data:

Angle Measurement

| | |
|---|---|
| Resolution | 0.03 seconds |
| Smallest unit in display | 0.1 seconds |

Standard Deviation

| | |
|---|---|
| Horizontal angle | 0.5 seconds |
| Vertical angle | 0.5 seconds |
| Distance measurement | 1mm + 1ppm |

Leica precision prisms were used as sighting targets.

## PERSONNEL

| | |
|---|---|
| Kendall Fancher | NOAA/NOS/NGS/GSD/I&M BRANCH<br>(540) 373-1243 |
| Dennis Lokken | NOAA/NOS/NGS/GSD?I&M BRANCH<br>(540) 373-1243 |

## LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008

### SURVEY METHODOLOGY

Four TRAVERSE CONTROL POINTS were set in locations surrounding the three launches in a manner allowing for a minimum of two independent measurements to each reference point and sensor. Coordinates of 5000.000 m for a Northing; 5000.000 m for an Easting; and 100.000 m for a Height were assumed for TRAVERSE CONTROL POINT 2. An azimuth of zero degrees was assumed between TRAVERSE CONTROL POINTS 2 and 3. A distance measurement and vertical and horizontal angles were taken to TRAVERSE CONTROL POINT 3, while occupying TRAVERSE CONTROL POINT 2. Thus, coordinates for TRAVERSE CONTROL POINT 3 were determined. A closed loop traverse was then undertaken through the 4 TRAVERSE POINTS in the following order; 2; 3; 4; and 1. During the traverse, two additional temporary control points were established (TP5 and TP6) to insure every sensor and reference point was independently measured at least twice. Every measurement was taken in both direct and reverse, with the 2nd measurement serving as a quality check.

### TRAVERSE CONTROL POINTS

| Point ID, | Northing, | Easting, | Height, | Description |
|---|---|---|---|---|
| 1, | 4999.80500, | 4982.73700, | 99.94500, | TRAVERSE CONTROL POINT 1 |
| 2, | 5000.00000, | 5000.00000, | 100.00000, | TRAVERSE CONTROL POINT 2 |
| 3, | 5061.00800, | 5000.00000, | 100.73700, | TRAVERSE CONTROL POINT 3 |
| 4, | 5050.64600, | 4980.04700, | 100.57800, | TRAVERSE CONTROL POINT 4 |
| 49, | 5040.95880, | 4990.44330, | 100.43130, | TP5 |
| 83, | 5027.24670, | 5005.98186, | 102.03031, | TP6 |

### AZIMUTH CHECKS

Id,Northing,Easting,Height,Description,Horizontal Error, Height Error

5,5061.00782,5000.00104,100.73794,AZ CK FROM 2 TO 3, HDIST = 0.0011,EDIFF = -0.001
6,4999.80503,4982.73711,99.94496,AZ CK FROM 2 TO 1, HDIST = 0.0001,EDIFF = 0.000
7,5061.00731,5000.00044,100.73845,AZ CK FROM 2 TO 3, HDIST = 0.0008,EDIFF = -0.001
8,5000.00002,4999.99763,99.99852,AZ CK FROM 3 TO 2, HDIST = 0.0024,EDIFF = 0.001
9,5050.64509,4980.04713,100.57767,AZ CK FROM 3 TO 4, HDIST = 0.0009,EDIFF = 0.000
10,5000.00119,5000.00254,99.99848,AZ CK FROM 3 TO 2, HDIST = 0.0028,EDIFF = 0.002
11,4999.80576,4982.74395,99.94282,AZ CK FROM 4 TO 1, HDIST = 0.0070,EDIFF = 0.002**,
12,5061.00783,5000.00044,100.73712,AZ CK FROM 4 TO 3, HDIST = 0.0005,EDIFF = 0.000
13,4999.99874,4999.99991,99.99982,AZ CK FROM 1 TO 2, HDIST = 0.0013,EDIFF = 0.000
14,4999.99887,4999.99990,99.99978,AZ CK TP5 TO 1, HDIST = 0.0011,EDIFF = 0.000
15,5050.64884,4980.04747,100.58414,AZ CK FROM TP5 TO 4, HDIST = 0.0029,EDIFF = -0.006
16,5019.02471,4989.97474,101.85042,AZ CK FROM 2 TO BM STEARN 2802,HDIST = 0.0028,EDIFF = -0.002
17,5026.32411,4988.76801,102.56877,AZ CK FROM TP6 TO BM BOW 2802, HDIST = 0.0043,EDIFF = -0.003

**Note—The azimuth check between station 4 to 1 constitutes the traverse loop closure.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

## REFERENCE FRAME INFORMATION

Survey data was collected for all three launches as a single data set, using a local reference frame. After reduction of the data, the sensor and reference points pertinent to each launch were parsed out of the combined data set to form launch specific groups of sensor and reference points. The original azimuth to each launch's STERN reference point was rotated such that a zero azimuth was established from those points through their corresponding BOW reference points. Coordinates were then translated to each launch's IMU. The launch reference frame can be defined as having a Northing (Y) axis running parallel with the centerline of the launch and running through the IMU reference point, positive from stern to bow. The Easting (X) axis is perpendicular to the centerline of the boat and is positive from the center of the IMU reference point towards the starboard side of the launch. The Height (Z) axis is positive in an upward direction from the IMU reference point. The IMU, for all three launches, is located at the origin of the reference frame possessing the following coordinates;

X = 0.000
Y = 0.000
Z = 0.000

## DISCUSSION

All units contained within this report are in meters.

After reviewing the check positions, the horizontal and vertical accuracy of the unadjusted values for all objects is +/- 1 Centimeter at the 95% confidence level.

The positions given for all GPS antenna are to the top center of the antenna. To correct the height value contained in the spreadsheet for each antenna to the Antenna Reference Point (ARP) or electronic phase center, the following steps should be taken;

1) Measure the total height of each antenna type. This information is located on the antenna or with equipment documentation.
2) Investigate to find the electronic phase center offset of the antenna. This information is probably located on the antenna or with equipment documentation. This value may also be available at the NGS website for antenna modeling.
3) Subtract the total height of the antenna from the spreadsheet Z value for each antenna. This will give you a Z value for the ARP (antenna reference point)
4) Add to this value the electronic phase center offset value appropriate for the antenna model.

## LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008

## STATION LISTING FOR NOAA LAUNCH 1101

| PT ID, | NORTHING, | EASTING, | HEIGHT, | PT DESCRIPTION |
|---|---|---|---|---|
| 1 | 1.229 | -0.916 | 3.348 | PORT SIDE GPS ANTENNA |
| 2 | 1.226 | 0.731 | 3.325 | STARBOARD SIDE GPS ANTENNA |
| 3 | 0.000 | 0.000 | 0.000 | IMU |
| 4 | -0.337 | -0.139 | -0.179 | BM KEEL |
| 5 | -3.101 | -0.110 | 1.356 | BM STERN |
| 6 | 3.158 | -0.110 | 1.548 | BM BOW |
| 7 | -0.869 | 0.396 | -0.431 | MULTIBEAM |
| 8 | 0.479 | 0.313 | -0.234 | MULTIBEAM BM 1101 |

## DESCRIPTION OF REFERENCE POINTS FOR NOAA LAUNCH 1101

**PORT SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**STARBOARD SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**IMU** = CENTER OF TARGET LOCATED ATOP IMU HOUSING.

**BM KEEL** = PUNCH MARK SET IN THE TOP CENTER OF THE KEEL, SET FORWARD 0.198 m FROM A BULKHEAD IN THE CABIN.

**STERN BM** = PUNCH MARK SET IN TOP CENTER OF A PICK POINT LOCATED NEAR THE STERN OF THE LAUNCH.

**BOW BM** = PUNCH MARK SET IN TOP CENTER OF A PICK POINT LOCATED NEAR THE BOW OF THE LAUNCH.

**MULTIBEAM** = CENTER OF MULTI-BEAM CAN.

**MULTIBEAM BM** = PUNCH MARK SET ALONG THE STARBOARD SIDE AND NEAR THE STERN END OF A PROTRUDING AREA OF THE HULL WITH A BLUE "CANOE" SHAPED OBJECT ATTACHED.

## LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008

## STATION LISTING FOR NOAA LAUNCH 2801

| PT ID, | NORTHING, | EASTING, | HEIGHT, | PT DESCRIPTION |
|---|---|---|---|---|
| 1 | -0.882 | -0.505 | 3.452 | PORT SIDE GPS ANTENNA |
| 2 | -0.885 | 0.495 | 3.456 | STARBOARD SIDE GPS ANTENNA |
| 3 | 0.000 | 0.000 | 0.000 | IMU |
| 4 | 0.352 | 0.241 | -0.477 | PLATE STAR |
| 5 | 0.352 | -0.239 | -0.478 | PLATE PORT |
| 6 | 0.535 | 0.004 | -0.606 | BM KEEL |
| 7 | -3.921 | -0.004 | 0.655 | BM STERN |
| 8 | 3.472 | -0.004 | 1.411 | BM BOW |
| 9 | -0.167 | 0.001 | 2.658 | BM CAB |
| 10 | 0.398 | -1.446 | 1.078 | BM PORT |
| 11 | 0.396 | 1.452 | 1.078 | BM STAR |

## DESCRIPTION OF REFERENCE POINTS FOR NOAA LAUNCH 2801

**PORT SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**STARBOARD SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**IMU** = CENTER OF TARGET LOCATED ATOP IMU HOUSING.

**PLATE STAR** = PUNCH MARK SET IN THE BOTTOM OF A METAL PLATE, IN-LINE WITH AND HALF DISTANCE BETWEEN TWO ALLEN BOLTS LOCATED ON THE STARBOARD SIDE OF THE LAUNCH TOWARDS THE STERN.

**PLATE PORT** = PUNCH MARK SET IN THE BOTTOM OF A METAL PLATE, IN-LINE AND HALF DISTANCE BETWEEN TWO ALLEN BOLTS LOCATED ON THE PORT SIDE OF THE LAUNCH TOWARDS THE STERN.

**BM KEEL** = PUNCH MARK SET IN CENTER OF THE KEEL, 0.125 FORWARD FROM THE TRAILING EDGE OF THE FORWARD KEEL.

**BM STERN** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DECK OF THE LAUNCH NEAR THE STERN AND ALONG THE CENTERLINE OF THE LAUNCH.

**BM BOW** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DECK OF THE LAUNCH NEAR THE BOW AND ALONG THE CENTERLINE OF THE LAUNCH.

**BM CAB** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE CAB OF THE LAUNCH AND ALONG THE CENTERLINE OF THE LAUNCH.

**BM PORT** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DEC OF THE LAUNCH, NEAR MID-SHIP AND ALONG THE PORT SIDE OF THE LAUNCH.

**BM STAR** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DEC OF THE LAUNCH, NEAR MID-SHIP AND ALONG THE STARBOARD SIDE OF THE LAUNCH.

## LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008

### STATION LISTING FOR NOAA LAUNCH 2802

| PT ID, | NORTHING, | EASTING, | HEIGHT, | PT DESCRIPTION |
|---|---|---|---|---|
| 1 | -0.882 | -0.495 | 3.451 | PORT SIDE GPS ANTENNA |
| 2 | -0.867 | 0.493 | 3.452 | STARBOARD SIDE GPS ANTENNA |
| 3 | 0.000 | 0.000 | 0.000 | IMU |
| 4 | 0.341 | 0.236 | -0.480 | PLATE STAR |
| 5 | 0.343 | -0.249 | -0.476 | PLATE PORT |
| 6 | 0.527 | -0.005 | -0.606 | BM KEEL |
| 7 | -3.926 | -0.004 | 0.671 | BM STERN |
| 8 | 3.475 | -0.004 | 1.388 | BM BOW |
| 9 | -0.162 | 0.004 | 2.655 | BM CAB |
| 10 | 0.396 | -1.448 | 1.077 | BM PORT |
| 11 | 0.395 | 1.448 | 1.076 | BM STAR |

### DESCRIPTION OF REFERENCE POINTS FOR NOAA LAUNCH 2802

**PORT SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**STARBOARD SIDE GPS ANTENNA** = TOP CENTER OF ANTENNA HOUSING.

**IMU** = CENTER OF TARGET LOCATED ATOP IMU HOUSING.

**PLATE STAR** = PUNCH MARK SET IN THE BOTTOM OF A METAL PLATE, IN-LINE WITH AND HALF DISTANCE BETWEEN TWO ALLEN BOLTS LOCATED ON THE STARBOARD SIDE OF THE LAUNCH TOWARDS THE STERN.

**PLATE PORT** = PUNCH MARK SET IN THE BOTTOM OF A METAL PLATE, IN-LINE AND HALF DISTANCE BETWEEN TWO ALLEN BOLTS LOCATED ON THE PORT SIDE OF THE LAUNCH TOWARDS THE STERN.

**BM KEEL** = PUNCH MARK SET IN CENTER OF THE KEEL, 0.125 FORWARD FROM THE TRAILING EDGE OF THE FORWARD KEEL.

**BM STERN** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DECK OF THE LAUNCH NEAR THE STERN AND ALONG THE CENTERLINE OF THE LAUNCH.

**BM BOW** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DECK OF THE LAUNCH NEAR THE BOW AND ALONG THE CENTERLINE OF THE LAUNCH.

**BM CAB** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE CAB OF THE LAUNCH AND ALONG THE CENTERLINE OF THE LAUNCH.

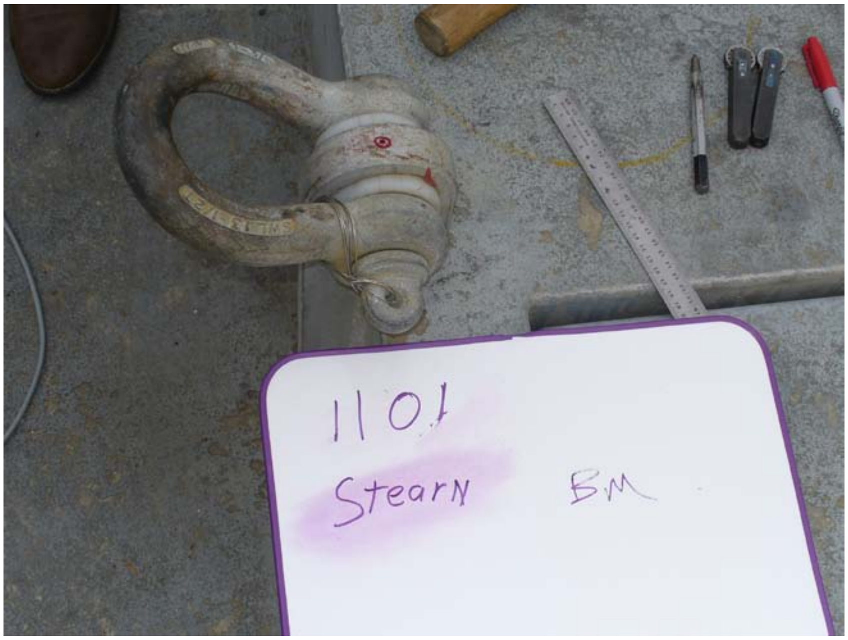
**BM PORT** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DEC OF THE LAUNCH, NEAR MID-SHIP AND ALONG THE PORT SIDE OF THE LAUNCH.

**BM STAR** = CENTER OF CROSS INSCRIBED INTO A METAL PLATE ATTACHED TO THE DEC OF THE LAUNCH, NEAR MID-SHIP AND ALONG THE STARBOARD SIDE OF THE LAUNCH.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 1101**


The reference point to both GPS antennas is the top center of the antenna housing.




STERN BM is a punch mark set in top center of the pick point located near the stern of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 1101**


BOW BM is a punch mark set in top center of the pick point located near the bow of the launch.


The reference point for the IMU is the center of the target atop the IMU housing.

Reference point BM KEEL is a punch mark set in the top center of the keel, set forward 0.198 from a bulkhead inside the cabin.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 1101**

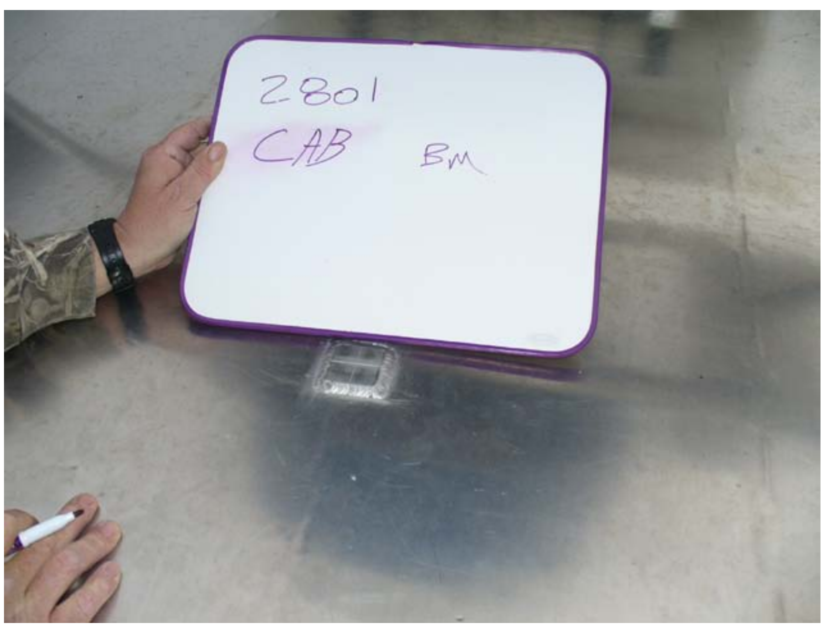

The reference point for the multi-beam sonar is the center of the can.


MULTIBEAM REF is a punch mark set along the starboard side and near the stern end of a protruding area of the hull with a blue "canoe" shaped object attached.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2801**


BM BOW is the center of a metal target attached to the deck of the launch and located near the bow of and along the centerline of the launch.

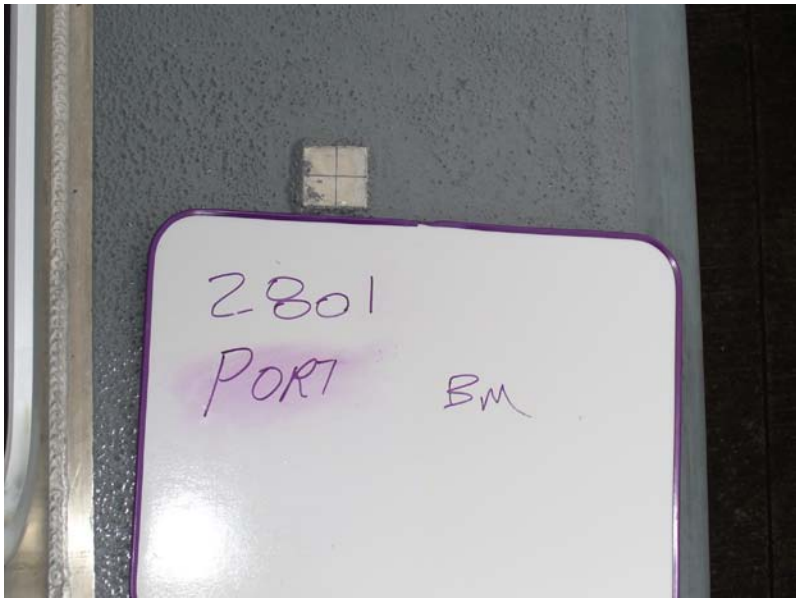



BM CAB is the center of a metal target attached to the deck of the launch and located atop the cab and near the centerline of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2801**


BM KEEL is a punch mark set in the center of and 0.125 forward from the trailing edge of the forward keel.




BM PORT is the center of a metal target attached to the deck of the launch and located along the port side of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2801**


BM STARBOARD is the center of a metal target attached to the deck of the launch and located along the starboard side of the launch.


BM STERN is the center of a metal target attached to the deck of the launch and located near the stern of and along the centerline of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2801**


The reference point to both GPS antennas is the top center of the antenna housing.


PLATE PORT is a punch mark set in the bottom of a metal plate, in-line and half distance between two allen bolts located on the port side of the launch and towards the stern.

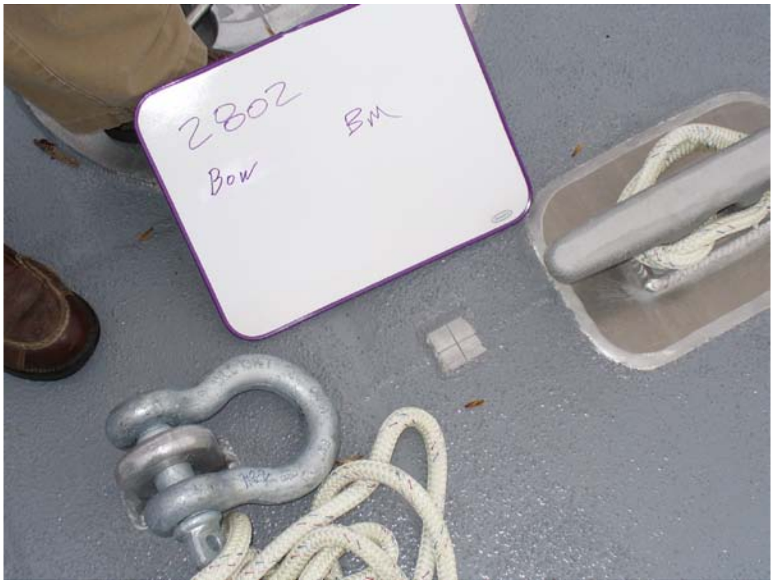
**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2801**


PLATE STAR is a punch mark set in the bottom of a metal plate, in-line and half distance between two allen bolts located on the starboard side of the launch and towards the stern.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2802**




BM BOW is the center of a metal target attached to the deck of the launch and located near the bow of and along the centerline of the launch.


BM CAB is the center of a metal target attached to the deck of the launch and located atop the cab and near the centerline of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

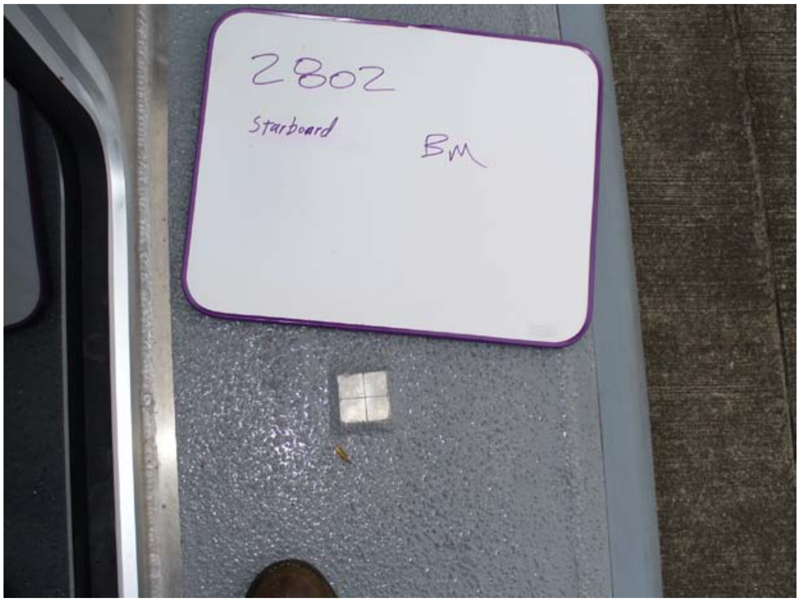
**IMAGES FOR NOAA LAUNCH 2802**


BM KEEL is a punch mark set in the center of and 0.125 forward from the trailing edge of the forward keel.

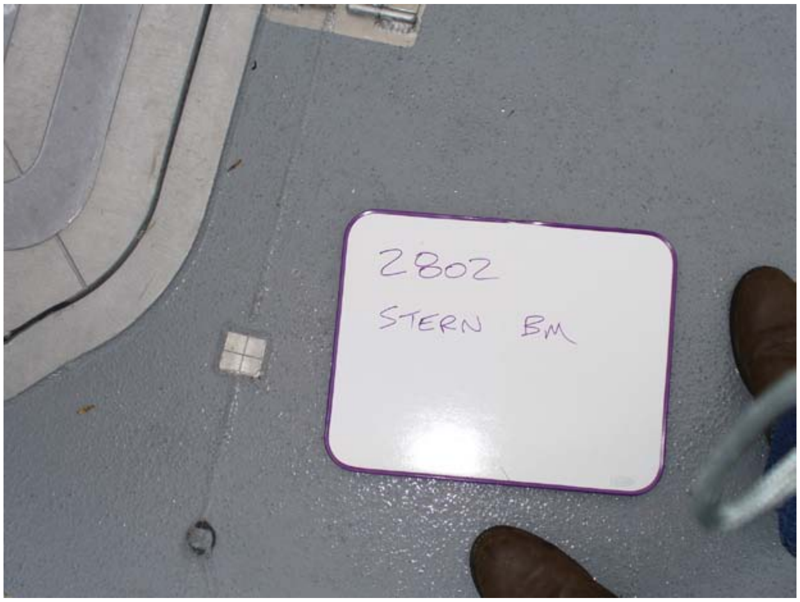

BM PORT is the center of a metal target attached to the deck of the launch and located along the port side of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2802**




BM STARBOARD is the center of a metal target attached to the deck of the launch and located along the starboard side of the launch.




BM STERN is the center of a metal target attached to the deck of the launch and located near the stern of and along the centerline of the launch.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2802**


The reference point to both GPS antennas is the top center of the antenna housing.


The reference point for the IMU is the center of the target atop the IMU housing.

**LAUNCH SPATIAL RELATIONSHIP SURVEYS – MARCH 2008**

**IMAGES FOR NOAA LAUNCH 2802**


PLATE PORT is a punch mark set in the bottom of a metal plate, in-line and half distance between two allen bolts located on the port side of the launch and towards the stern.


PLATE STAR is a punch mark set in the bottom of a metal plate, in-line and half distance between two allen bolts located on the starboard side of the launch and towards the stern.

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GEODETIC SERVICES DIVISION
INSTRUMENTATION & METHODOLOGIES BRANCH

# NOAA SURVEY VESSEL 2803
# POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY
# FIELD REPORT

Kendall L. Fancher
March, 2009

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## PURPOSE

The primary purpose of the survey was to precisely determine the spatial relationship between various hydrographic surveying sensors, and the components of a POS MV navigation system aboard the NOAA survey vessel 2803.

## PROJECT DETAILS

This survey was conducted in Seattle, WA on the $17^{th}$ of March, 2009. The weather was cool and cloudy. For this survey, the vessel was on blocks and supported by boat jacks. The vessel was reported to have been leveled relative to the IMU.

## INSTRUMENTATION

A Leica (Wild) TC2003 precision total station was used to make all measurements.
Technical Data:

Standard Deviation

| | |
|---|---|
| Horizontal angle | 0.5 seconds |
| Vertical angle | 0.5 seconds |
| Distance measurement | 1mm + 1ppm |

Standard precision prisms were used as sighting targets. Prisms were configured to have a zero mm offset.

## PERSONNEL


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(540) 373-1243

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(540) 373-1243

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## DEFINITION OF THE REFERENCE FRAME

To conduct this survey a local coordinate reference frame was established where the Northing (Y) axis runs along the centerline of the boat and is positive from the IMU towards the bow of the boat. The Easting (X) axis is perpendicular to the centerline of the boat and is positive from the IMU towards the right, when looking at the boat from the stern. The Up (Z) axis is positive in an upward direction from the IMU.

## SURVEY METHODOLOGY

Four temporary control points, (1, 2, 3, and 4), were established around the vessel such that every point to be positioned on the launch could be observed from at least two separate locations.

Coordinates of 100.000N, 100.000E, and 100.000U were assumed for control point 1. A distance and height difference were measured between control points 1 and 2. These values were used to determine the coordinates for control point.

Control point 1 was occupied and control point 2 was observed for a backsight. After initialization, control point 4 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 2 was occupied and control point 1 was observed for a backsight. After initialization, control point 3 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 3 was occupied and control point 2 was observed for a backsight. After initialization, control point 3 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 4 was occupied and control point 3 was observed for a backsight. After initialization, all visible points to be observed on the launch were observed in both direct and reverse. Control point 1 was also observed in order to evaluate the accuracy of the traverse. Inverse computations between the original and observed control point yielded a horizontal accuracy of 0.002m and a vertical accuracy of -0.001m.

Inverses were computed between the two positions determined for all points surveyed to evaluate the accuracy of the survey.

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

The reference frame was rotated using CENTERLINE STERN BM (BMS) as the point of rotation. A zero degree azimuth was used during the rotation from BMS to CENTERLINEN BOW BM (BMB).

The reference frame was then translated to relocate the origin of the reference frame to the IMU.

## INVERSE RESULTS

***Inverses were computed between the two occupations of each positioned point. The results of these inverses are:***

| ID | Horizontal Dist.(m) | Elevation Diff(m) |
|---|---|---|
| AFT | 0.0012 | 0.0040 |
| FORE | 0.0011 | 0.0037 |
| GPSP | 0.0010 | 0.0041 |
| GPSS | 0.0005 | -0.0004 |
| BMS | 0.0008 | 0.0039 |
| BMB | 0.0063 | -0.0046 |
| BMMP | 0.0016 | -0.0008 |
| BMMS | 0.0003 | 0.0000 |
| BMC | 0.0008 | -0.0045 |
| IMU | 0.0110 | 0.0037 |

## DISCUSSION

The positions given for the POS GPS antennas (Zephyr p/n 39105-00) are to the top center of the antenna. To correct the Z value provided in this report for each antenna to the electronic phase center, I recommend the following steps be taken;

1) Determine the physical height of the GPS antenna. This information is probably located on the antenna or with equipment documentation.
2) Investigate to find the electronic phase center offset of the antenna. This information is probably located on the antenna or with equipment documentation. This value may also be available at the NGS website for antenna modeling.
3) Subtract the total height of the antenna from the Z value for each antenna. This will give you a Z value for the antenna ARP (antenna reference point)
4) Then add to this value the electronic phase center offset value appropriate for the antenna model.

The multi-beam transducers were not positioned this survey. Two reference points (FORE and AFT) were positioned in order to accomplish this task at a later date. Refer to Attachment A. for descriptions of these two reference points.

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## Station Listing

| | |
|---|---|
| BMB- | CENTERLINE BOW BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the deck, along the centerline and near the bow of the launch. |
| BMS- | CENTERLINE STERN BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the deck, along the centerline and near the stern of the launch. |
| BMC- | CENTERLINE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the cab, along the centerline of the launch. |
| BMMP- | PORT SIDE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the deck, near the middle of and along the port side of the launch. |
| BMMS- | STARBOARD SIDE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the deck, near the middle of and along the starboard side of the launch. |
| FORE- | KEEL BM<br>A punch mark set along the bottom center of the keel, fore of the multi-beam transducer, 0.037m from a point where the keel makes a 90 degree angle upwards. |
| AFT- | KEEL BM<br>A punch mark set along the bottom center of the keel, aft of the multi-beam transducer, 0.018m from a point where the keel makes a 45 degree angle upwards. |
| IMU- | IMU REFERENCE TARGET<br>Center of a target affixed to the top of the IMU housing. |
| GPSP- | PORT SIDE GPS ANTENNA REFERENCE POINT<br>The top center of the port side GPS antenna for the POS system. |
| GPSS- | STARBOARD GPS ANTENNA REFERENCE POINT<br>The top center of the starboard side GPS antenna for the POS system. |

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## Coordinate Listing using IMU as the Reference Frame Origin

| CONTROL POINT NAME | ID | X(NORTH)m | Y(EAST)m | Z(UP)m |
|---|---|---|---|---|
| IMU REFERENCE TARGET | IMU | 0.000 | 0.000 | 0.000 |
| PORT SIDE GPS ANTENNA REFERENCE POINT | GPSP | -0.815 | -0.665 | 3.163 |
| STARBOARD GPS ANTENNA REFERENCE POINT | GPSS | -0.805 | 0.704 | 3.163 |
| CENTERLINE STERN BM | BMS | -4.080 | 0.008 | 0.690 |
| PORT SIDE BM | BMMP | 0.079 | -1.451 | 1.074 |
| STARBOARD SIDE BM | BMMS | 0.100 | 1.467 | 1.059 |
| CENTERLINE BOW BM | BMB | 3.438 | 0.008 | 1.396 |
| CENTERLINE BM | BMC | -0.201 | 0.012 | 2.668 |
| KEEL BM | AFT | -0.598 | -0.005 | -0.728 |
| KEEL BM | FORE | 0.420 | -0.005 | -0.619 |

**NOAA SURVEY VESSEL 2803**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

**ATTACHMENT A.**

US DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL GEODETIC SURVEY
GEODETIC SERVICES DIVISION
INSTRUMENTATION & METHODOLOGIES BRANCH

# NOAA SURVEY VESSEL 2804
# POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY
# FIELD REPORT

Kendall L. Fancher
March, 2009

**NOAA SURVEY VESSEL 2804**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## PURPOSE

The primary purpose of the survey was to precisely determine the spatial relationship between various hydrographic surveying sensors, and the components of a POS MV navigation system aboard the NOAA survey vessel 2804.

## PROJECT DETAILS

This survey was conducted in Seattle, WA on the $17^{th}$ of March, 2009. The weather was cool and cloudy. For this survey, the vessel was on blocks and supported by boat jacks. The vessel was reported to have been leveled relative to the IMU.

## INSTRUMENTATION

A Leica (Wild) TC2003 precision total station was used to make all measurements.
Technical Data:

Standard Deviation

| | |
|---|---|
| Horizontal angle | 0.5 seconds |
| Vertical angle | 0.5 seconds |
| Distance measurement | 1mm + 1ppm |

Standard precision prisms were used as sighting targets. Prisms were configured to have a zero mm offset.

## PERSONNEL


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**NOAA SURVEY VESSEL 2804**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## DEFINITION OF THE REFERENCE FRAME

To conduct this survey a local coordinate reference frame was established where the Northing (Y) axis runs along the centerline of the boat and is positive from the IMU towards the bow of the boat. The Easting (X) axis is perpendicular to the centerline of the boat and is positive from the IMU towards the right, when looking at the boat from the stern. The Up (Z) axis is positive in an upward direction from the IMU.

## SURVEY METHODOLOGY

Four temporary control points, (1, 2, 3, and 4), were established around the vessel such that every point to be positioned on the launch could be observed from at least two separate locations.

Coordinates of 100.000N, 100.000E, and 100.000U were assumed for control point 1. A distance and height difference were measured between control points 1 and 2. These values were used to determine the coordinates for control point.

Control point 1 was occupied and control point 2 was observed for a backsight. After initialization, control point 4 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 2 was occupied and control point 1 was observed for a backsight. After initialization, control point 3 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 3 was occupied and control point 2 was observed for a backsight. After initialization, control point 3 and all visible points to be observed on the launch were observed in both direct and reverse.

Control point 4 was occupied and control point 3 was observed for a backsight. After initialization, all visible points to be observed on the launch were observed in both direct and reverse. Control point 1 was also observed in order to evaluate the accuracy of the traverse. Inverse computations between the original and observed control point yielded a horizontal accuracy of 0.002m and a vertical accuracy of -0.001m.

Inverses were computed between the two positions determined for all points surveyed to evaluate the accuracy of the survey.

**NOAA SURVEY VESSEL 2804**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

The reference frame was rotated using CENTERLINE STERN BM (BMS) as the point of rotation. A zero degree azimuth was used during the rotation from BMS to CENTERLINEN BOW BM (BMB).

The reference frame was then translated to relocate the origin of the reference frame to the IMU.

## INVERSE RESULTS

***Inverses were computed between the two occupations of each positioned point. The results of these inverses are:***

| ID | Horizontal Dist.(m) | Elevation Diff(m) |
|---|---|---|
| AFT | 0.0010 | - 0.0012 |
| FORE | 0.0027 | - 0.0031 |
| GPSP | 0.0032 | 0.0037 |
| GPSS | 0.0012 | 0.0042 |
| BMS | 0.0024 | - 0.0071 |
| BMB | 0.0133 | 0.0025 |
| BMMP | 0.0080 | 0.0043 |
| BMMS | 0.0011 | - 0.0004 |
| BMC | 0.0029 | 0.0041 |
| IMU | 0.0019 | -0.0049 |

## DISCUSSION

The positions given for the POS GPS antennas (Zephyr p/n 39105-00) are to the top center of the antenna. To correct the Z value provided in this report for each antenna to the electronic phase center, I recommend the following steps be taken;

1) Determine the physical height of the GPS antenna. This information is probably located on the antenna or with equipment documentation.
2) Investigate to find the electronic phase center offset of the antenna. This information is probably located on the antenna or with equipment documentation. This value may also be available at the NGS website for antenna modeling.
3) Subtract the total height of the antenna from the Z value for each antenna. This will give you a Z value for the antenna ARP (antenna reference point)
4) Then add to this value the electronic phase center offset value appropriate for the antenna model.

The multi-beam transducers were not positioned this survey. Two reference points (FORE and AFT) were positioned in order to accomplish this task at a later date. Refer to Attachment A. for descriptions of these two reference points.

**NOAA SURVEY VESSEL 2804**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## Station Listing

| | |
|---|---|
| BMB- | CENTERLINE BOW BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the deck, along the centerline and near the bow of the launch. |
| BMS- | CENTERLINE STERN BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the deck, along the centerline and near the stern of the launch. |
| BMC- | CENTERLINE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the cab, along the centerline of the launch. |
| BMMP- | PORT SIDE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the deck, near the middle of and along the port side of the launch. |
| BMMS- | STARBOARD SIDE BM<br>The center of a cross mark inscribed into the top of a square metal flange, welded to the top of the deck, near the middle of and along the starboard side of the launch. |
| FORE- | KEEL BM<br>A punch mark set along the bottom center of the keel, fore of the multi-beam transducer, 0.037m from a point where the keel makes a 90 degree angle upwards. |
| AFT- | KEEL BM<br>A punch mark set along the bottom center of the keel, aft of the multi-beam transducer, 0.018m from a point where the keel makes a 45 degree angle upwards. |
| IMU- | IMU REFERENCE TARGET<br>Center of a target affixed to the top of the IMU housing. |
| GPSP- | PORT SIDE GPS ANTENNA REFERENCE POINT<br>The top center of the port side GPS antenna for the POS system. |
| GPSS- | STARBOARD GPS ANTENNA REFERENCE POINT<br>The top center of the starboard side GPS antenna for the POS system. |

NOAA SURVEY VESSEL 2804
POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY

**Coordinate Listing using IMU as the Reference Frame Origin**

| CONTROL POINT NAME | ID | X(NORTH)m | Y(EAST)m | Z(UP)m |
|---|---|---|---|---|
| IMU REFERENCE TARGET | IMU | 0.000 | 0.000 | 0.000 |
| PORT SIDE GPS ANTENNA REFERENCE POINT | GPSP | -0.845 | -0.645 | 3.150 |
| STARBOARD GPS ANTENNA REFERENCE POINT | GPSS | -0.844 | 0.713 | 3.143 |
| CENTERLINE BOW BM | BMB | 3.430 | 0.013 | 1.431 |
| CENTERLINE STERN BM | BMS | -4.084 | 0.013 | 0.663 |
| CENTERLINE BM | BMC | -0.226 | 0.025 | 2.662 |
| PORT SIDE BM | BMMP | 0.067 | -1.438 | 1.078 |
| STARBOARD SIDE BM | BMMS | 0.077 | 1.475 | 1.059 |
| KEEL BM | AFT | -0.609 | 0.003 | -0.733 |
| KEEL BM | FORE | 0.413 | 0.009 | -0.613 |

**NOAA SURVEY VESSEL 2804**
**POS MV COMPONENTS SPATIAL RELATIONSHIP SURVEY**

## ATTACHMENT A.

Report of Measurements:
Alignment Support and
As-Builting

# NOAA Rainier

Work performed at
Vigor Marine LLC
Portland, OR

Westlake
consultants, inc

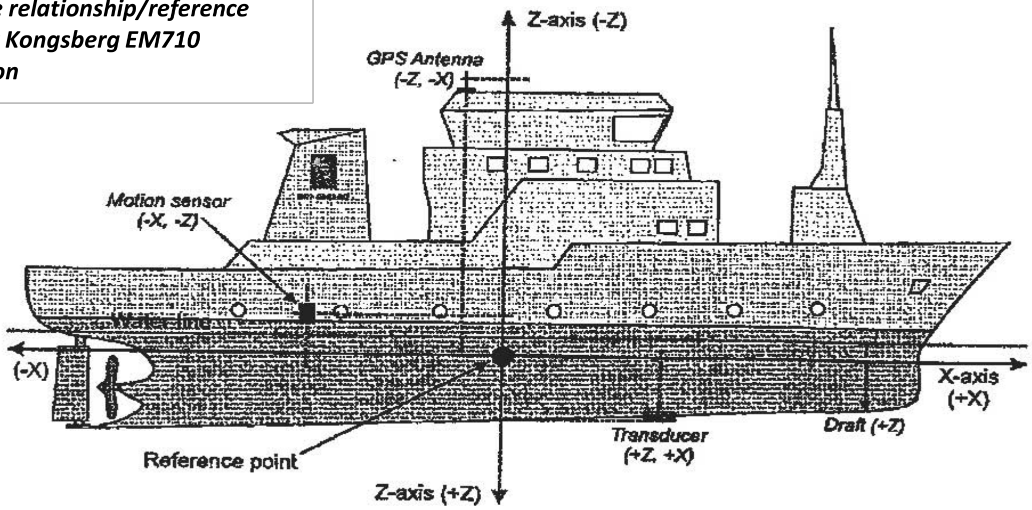
October 12, 2010

## CONTENTS

## CONTENTS - APPENDIX EXHIBITS

## Definitions and Basis for Dimensions/Locations/Pitch/Roll/Heading

***Coordinate relationship/reference system per Kongsberg EM710 specification***




### Northings

Northings (Port - Starboard) are with reference to the Granite Block centerline scribe.
Positive values are starboard of the Granite Block.
Negative values are port of the Granite Block.

### Eastings

Eastings (Stern to Bow ) are with reference to the Granite Block centerline scribe.
Positive values are forward of the Granite Block.
Negative values are aft of the Granite Block.

### Elevations

Elevations are with reference to the Granite Block centerline scribe = 0 elevation.
Positive values are below the Granite Block (toward the keel).
Negative values are toward the topside.

### Dimensions

All dimensions are in feet and decimal feet as well as metric (meters are noted in blue and are italicized).
All dimensions provided are "offsets" to the centerline of the granite block.
Heading, Pitch, and Roll are reported in decimal degrees.

### Ship's Centerline Data

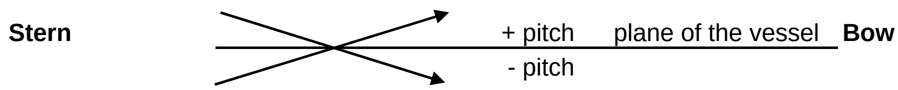
At project initiation, control was established to define the ship's centerline as a plane running from a point on the centerline of the keel at the stern through a point on the centerline of the keel near the bow, to a point on the bow.
This is the Centerline Vertical Keel or CVK.

## Granite Block Reference Data - Procedure

All data was originally referenced to the ship's geometry.
Following location of the Granite Block, data was transformed to the Granite Block as point of origin for Northings, Eastings, and Elevation. All dimensions provided with reference to the Granite Block are "offsets."

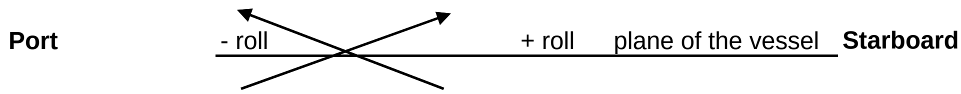
## Pitch

Pitch is defined as angular deviation from the horizontal plane of the vessel along the length of the vessel.
The pitch is positive if the easting axis points upward, and
pitch is negative if the easting axis points downwards.
(Definition assumes ship is upright and level in the water.)



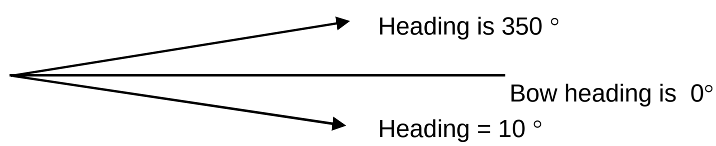

## Roll

Roll is defined as angular deviation from the horizontal plane of the vessel across the vessel (port - starboard).
A positive roll is observed when the northing axis points upwards toward the starboard,
and roll is negative when it points upward towards the port.
(Definition assumes ship is upright in the water.)




## Heading

Heading is defined as the angular deviation of the vector of an object from the direction of the bow.
(Definition assumes ship is upright in the water.)



## Ship's Geometry / Centerline Vertical Keel

The Centerline vertical keel (CVK) was defined as the plane passing through three points on the bottom of the keel; one midship, one at approximate frame 31, and a point offset 1.04' to the starboard at the stern. The fourth point was at the bow at the centerline of the anchor chock on the main deck.

| **Relative Locations of CVK Reference Points** | | **Data per Granite Block as (0,0,0)** | | | **Raw Data** | | |
|---|---|---|---|---|---|---|---|
| | | ***Starboard-Port*** | ***Forward-Aft*** | ***Elevation*** | ***Northing/Port**** | ***Easting/Forward*** | ***Elevation*** |
| **Point 100** Bottom of keel at stern, offset 1.04' starboard | decimal feet | **4.953** | **-83.222** | **13.006** | **-1.042** | **-0.003** | **0.001** |
| | ***metric*** | *1.510* | *-25.366* | *3.964* | *-0.318* | *-0.001* | *0.000* |
| **Point 101** Bottom of keel Midship | decimal feet | **3.912** | **-11.874** | **13.117** | **-0.001** | **71.345** | **-0.111** |
| | ***metric*** | *1.193* | *-3.619* | *3.998* | *0.000* | *21.746* | *-0.034* |
| **Point 102** Bottom of keel Frame 31 (approx) | decimal feet | **3.911** | **29.620** | **13.007** | **0.000** | **112.839** | **0.000** |
| | ***metric*** | *1.192* | *9.028* | *3.965* | *0.000* | *34.393* | *0.000* |
| **Point 103** CL Anchor chock at bow of Maindeck | decimal feet | **3.911** | **92.328** | **-21.853** | **0.000** | **175.547** | **34.860** |
| | ***metric*** | *1.192* | *28.142* | *-6.661* | *0.000* | *53.507* | *10.625* |

** Note that **in the raw data** negative values are starboard, positive are to port.*

*Values in blue italics are metric; bold values are decimal feet.*

## Granite Block

| | *Starboard - Port* | **Forward - Aft** | *ELEVATION* |
|---|---|---|---|
| **As Point of Origin** | **0.000** | **0.000** | **0.000** |
| ***metric*** | ***0.000*** | ***0.000*** | ***0.000*** |
| Horizontal alignment per scribed lines on Granite Block - **RAW DATA (meters)** | **3.911** | **83.219** | **13.007** |
| ***metric*** | ***1.192*** | ***25.365*** | ***3.965*** |

- See Appendix for Exhibit # 1 with photos illustrating location of granite block.
- The granite block is 1.1921 meters ( or 3.911 feet) port of ship's centerline. (Note: in raw data starboard values are negative.)
- The block is located 3.965 meters (13.007 feet) feet above the ship's baseline/datum on the keel, bottom of bottom keel plate.
- The centerline of the granite block is located 25.365 meters (83.205 feet) forward of the point of beginning on the keel at the stern of the vessel.

## IMU Mounting Plate Opening/Bolt Hole

| | *Starboard - Port* | **Forward - Aft** | *ELEVATION* |
|---|---|---|---|
| **Relative to Granite Block** | | | |
| Bolt Hole/Centerline of IMU Mounting Plate | **-1.844** | **0.067** | **0.395** |
| ***metric*** | ***-0.562*** | ***0.020*** | ***0.120*** |
| **RAW DATA** | | | |
| Bolt Hole/Centerline of IMU Mounting Plate | **5.755** | **83.286** | **12.612** |
| ***metric*** | ***1.754*** | ***25.385*** | ***3.844*** |

- See Appendix for Exhibit # 2 with photos illustrating the "IMU Mounting Plate Bolt Hole/Opening" location.
- IMU mounting block is aligned 1.844 feet port of the Granite Block.
- Location is 0.067 feet forward of Granite Block.
- The IMU mounting plate elevation was calculated based on the elevation measurements taken on the plate.

## Gondola Verification

### GONDOLA ARRAY BASE PLATE FLATNESS VERIFICATION

- "Best fit plane" for the Gondola base plate flatness checks was calculated using four reference marks: Points 5, 6, 7, and 8 on Exhibit # 3.

- Deviations ranged from + 0.5 mm to - 2.3 mm. (Note that a positive number indicates a point extending below the plane of the Gondola flat bottom when the Gondola is in its upright position).

- Note that all gondola measurements were performed during fabrication not after alignment onto the ship.

- ***See Exhibit # 3 for Gondola Base Plate flatness checks*** .

### GONDOLA ARRAY CUT-OUT CHECKS: ANGULAR DEFLECTION

- The centerline of the Gondola was marked by Vigor Marine staff. The gondola centerline aligned with the Ship's centerline.

- The TX Array cut-out was angled 0.0170˚ to the starboard. The forward starboard corner is 0.3 mm starboard of parallel to the centerline.

- The RX Array cut-out aft face was at a 90.0440˚ angle (0.0440˚ from perpendicular to the Gondola centerline. The aft starboard corner of the cut-out was 0.4 mm aft of design.

- Note that all gondola measurements were performed during fabrication not after alignment onto the ship.

- ***See Exhibit # 4 for Gondola Sonar Array Cut-Out checks*** .

## SONAR Array/Transducer Acoustic Centers

| Kongsberg EM 710 | Starboard - Port | Forward - Aft | ELEVATION | HEADING | PITCH | ROLL |
|---|---|---|---|---|---|---|
| **RECEIVER ARRAY** | | | | 90.019° | 0° | -0.030° |
| **Transverse array** | 3.913 | 21.468 | 14.950 | | | |
| *metric* | *1.193* | *6.543* | *4.557* | | | |
| **TRANSMITTER ARRAY - Forward** | | | | 359.919° | -0.012° | -0.034° |
| **Longitudinal array** | 4.258 | 24.923 | 14.952 | | | |
| *metric* | *1.298* | *7.597* | *4.557* | | | |
| **TRANSMITTER ARRAY - Aft** | | | | 0.037° | -0.012° | -0.069° |
| **Longitudinal array** | 4.256 | 28.115 | 14.951 | | | |
| *metric* | *1.297* | *8.570* | *4.557* | | | |

* The coordinates represent the centerline at the bottom of the arrays - relative to the granite block (0,0,0).

* The elevation at the center of the bottom of the array is provided per direction from Kongsberg representative.

## SONAR Array/Transducer Foundation Flatness (Plane) Checks

**TX Array**: Maximum deviations were +/- 0.2 mm from the plane.

**RX Array**: Maximum deviation was + 0.1 mm from the plane.

**NOTE:** The deviations reflect offsets to a single "best fit plane" calculated from all points (6 points on the RX array and 10 points on the TX array). NOTE that positive deviation indicates that the sonar array foundation extends below the best fit plane, negative numbers indicate points above that plane.

**NOTE:** Per Kongsberg, the specification/tolerance for flatness is +/- 0.2 mm from the plane

***See Exhibit # 5 illustrating deviations from the best fit plane for each array.***

## Frame Locations - Exterior at Hull

| | | Data per Granite Block as (0,0,0) | | | Raw Data (Per Vessel Geometry) | | |
|---|---|---|---|---|---|---|---|
| | | *Starboard - Port ** | Forward - Aft | *ELEVATION ** | *Starboard - Port ** | Forward - Aft | *ELEVATION ** |
| **Frame 26** | | 0.294 | **33.666** | 12.007 | 3.617 | **116.885** | 1.000 |
| (point 108) | *metric* | *0.090* | ***10.262*** | *3.660* | *1.103* | ***35.627*** | *0.305* |
| **Frame 31** | | 3.863 | **24.933** | 13.005 | 0.049 | **108.152** | 0.002 |
| (point 109) | *metric* | *1.177* | ***7.600*** | *3.964* | *0.015* | ***32.965*** | *0.001* |
| **Frame 32** | | 1.552 | **23.160** | 12.777 | 2.359 | **106.379** | 0.230 |
| (point 110) | *metric* | *0.473* | ***7.059*** | *3.894* | *0.719* | ***32.424*** | *0.070* |
| **Frame 33** | | 1.562 | **21.467** | 12.805 | 2.349 | **104.686** | 0.202 |
| (point 111) | *metric* | *0.476* | ***6.543*** | *3.903* | *0.716* | ***31.908*** | *0.062* |
| **Frame 34** | | -0.740 | **19.755** | 12.508 | 4.651 | **102.973** | 0.499 |
| (point 106) | *metric* | *-0.226* | ***6.021*** | *3.812* | *1.418* | ***31.386*** | *0.152* |
| **Frame 35** | | -0.772 | **17.995** | 12.562 | 4.683 | **101.214** | 0.445 |
| (point 107) | *metric* | *-0.235* | ***5.485*** | *3.829* | *1.428* | ***30.850*** | *0.136* |

*** Note:** The elevation at each measurement point was random. The port-starboard values also reflect elevation differences.

**Note:** Shots were taken on the exterior of the hull at points marked on the hull by Vigor Marine personnel.

## Reference Marks

**NOTE:** Photos and further identification of these reference marks are provided in the Appendix.

| | Data per Granite Block as (0,0,0) | | | Raw Data (Per Vessel Geometry) | | |
|---|---|---|---|---|---|---|
| | *Starboard - Port* | Forward - Aft | *ELEVATION* | *Starboard - Port* | Forward - Aft | *ELEVATION* |
| **IMU Bolt Hole** | | | | | | |
| | **-1.844** | **0.067** | **0.395** | **5.755** | **83.286** | **12.612** |
| ***metric*** | ***-0.562*** | ***0.020*** | ***0.120*** | ***1.754*** | ***25.385*** | ***3.844*** |
| *See Appendix Exhibit # 2* | | | | | | |
| **POS/MV Antenna Mounting Bases** | | | | | | |
| **Starboard** | **6.913** | **-39.369** | **-43.348** | **-3.002** | **43.850** | **56.355** |
| ***metric*** | ***2.107*** | ***-12.000*** | ***-13.212*** | ***-0.915*** | ***13.366*** | ***17.177*** |
| **Port** | **0.368** | **-39.454** | **-43.307** | **3.543** | **43.765** | **56.314** |
| ***metric*** | ***0.112*** | ***-12.026*** | ***-13.200*** | ***1.080*** | ***13.340*** | ***17.165*** |
| *See Appendix Exhibit # 6* | | | | | | |
| **Flying Bridge Aft: Centerline of Bolt** | | | | | | |
| **Secured in AFT Railing** | | | | | | |
| | **3.665** | **-39.224** | **-34.935** | **0.246** | **43.995** | **47.942** |
| ***metric*** | ***1.117*** | ***-11.956*** | ***-10.648*** | ***0.075*** | ***13.410*** | ***14.613*** |
| *See Appendix Exhibit # 7* | | | | | | |
| **Fantail Deck near Stern:** | | | | | | |
| **Stern rail bolt centerline on top of bulwark** | | | | | | |
| **Starboard** | **21.624** | **-108.284** | **-11.019** | **-17.713** | **-25.065** | **24.026** |
| (on Gunnel) ***metric*** | ***6.591*** | ***-33.005*** | ***-3.359*** | ***-5.399*** | ***-7.640*** | ***7.323*** |
| **Port** | **-13.500** | **-110.898** | **-10.714** | **17.411** | **-27.679** | **23.721** |
| (on Anchor Chock) ***metric*** | ***-4.115*** | ***-33.802*** | ***-3.266*** | ***5.307*** | ***-8.437*** | ***7.230*** |
| *See Appendix Exhibits # 8 and 9* | | | | | | |

## Reference Marks, cont.

| | Data per Granite Block as (0,0,0) | | | Raw Data (Per Vessel Geometry) | | |
|---|---|---|---|---|---|---|
| | ***Starboard - Port*** | **Forward - Aft** | ***ELEVATION*** | ***Starboard - Port*** | **Forward - Aft** | ***ELEVATION*** |
| **Bow: Bolt secured forward of Jack Staff** | | | | | | |
| | **3.936** | **93.418** | **-25.347** | **-0.025** | **176.637** | **38.354** |
| ***metric*** | *1.200* | *28.474* | *-7.726* | *-0.008* | *53.839* | *11.690* |
| *See Appendix Exhibit # 10* | | | | | | |
| **Stern Bulkhead: Bolt set in aft-facing** | | | | | | |
| **wall near centerline (accessible from D deck)** | | | | | | |
| | **4.370** | **-93.806** | **-14.095** | **-0.459** | **-10.587** | **27.102** |
| ***metric*** | *1.332* | *-28.592* | *-4.296* | *-0.140* | *-3.227* | *8.261* |
| *See Appendix Exhibit # 11* | | | | | | |
| **Aft-Facing IMU Closet Wall in Room C-4:** | | | | | | |
| **Bolt in Exterior Aft-Facing Wall of IMU Closet near centerline** | | | | | | |
| | **-1.177** | **-1.403** | **-3.943** | **5.088** | **81.816** | **16.949** |
| ***metric*** | *-0.359* | *-0.428* | *-1.202* | *1.551* | *24.937* | *5.166* |
| *See Appendix Exhibit # 12* | | | | | | |
| **Under Hull Reference Marks "SET"** | | | | | | |
| **SS plates near Gondola (near and port of centerline)** | | | | | | |
| **553** | **3.909** | **17.160** | **13.062** | **0.002** | **100.379** | **-0.055** |
| ***metric*** | *1.192* | *5.231* | *3.981* | *0.001* | *30.596* | *-0.017* |
| 554 | **3.910** | **31.787** | **13.023** | **0.001** | **115.006** | **-0.016** |
| ***metric*** | *1.192* | *9.689* | *3.969* | *0.000* | *35.054* | *-0.005* |
| 555 | **-2.702** | **36.632** | **10.043** | **6.613** | **119.850** | **2.964** |
| ***metric*** | *-0.824* | *11.165* | *3.061* | *2.016* | *36.530* | *0.903* |
| 556 | **-9.267** | **4.120** | **11.565** | **13.178** | **87.339** | **1.442** |
| ***metric*** | *-2.825* | *1.256* | *3.525* | *4.017* | *26.621* | *0.440* |
| *See Appendix Exhibit # 13* | | | | | | |

**Westlake Consultants, Inc.**
15115 SW Sequoia Parkway (Suite 150)
Tigard, Oregon  97224
503-684-0652

## DRAFT Marks

**Notes:**

--- Elevation data is based on measurements taken at the bottom of the welded draft mark numbers.

--- Data is reported for the forward marks on the starboard side and aft marks on the port side.

**--- Elevations are reported in decimal feet only, relative to the keel "0" elevation.**

--- Elevation does not relate to the gondola or to the granite block.

| | Elevation Starboard - Forward | Elevation Port - Aft |
|---|---|---|
| **7 Draft Mark** | 6.99 | |
| **8 Draft Mark** | 8.01 | 8.02 |
| **9 Draft Mark** | 9.01 | 9.01 |
| **10 Draft Mark** | 10.02 | 10.02 |
| **11 Draft Mark** | 11.01 | 11.04 |
| **12 Draft Mark** | 12.01 | 12.01 |
| **13 Draft Mark** | 13.03 | 13.03 |
| **14 Draft Mark** | 14.03 | 14.01 |
| **15 Draft Mark** | 15.01 | 14.99 |
| **16 Draft Mark** | 16.02 | 15.98 |
| **17 Draft Mark** | 17.01 | 16.97 |

## Measurement (As-Built) Tolerances

### Granite Block

Defined as the point of origin (0,0,0), there is no error associated with this location.
Note that on the NOAA Rainier two parallel lines were scribed on the block, but there was no intersecting line.
We calculated the mid-point of the granite block using the mid-point of the scribe line. (The inboard line was used per direction from a Ship's representative.)

### IMU Mounting Plate

Tolerance for offset location = ± 1.0 mm ( ± 0.003 feet)

### Multi-Beam Arrays

**Kongsberg EM-710 RECEIVER ARRAY**

**Kongsberg EM-710 TRANSMITTER ARRAY**

Tolerance for level = ± 0.2 mm ( ± 0.008 inches or ± 0.001 feet)

Tolerance for offset location of array center = ± 1.0 mm ( ± 0.0033 feet)

### Gondola

**NOTE:** Gondola was verified during fabrication, not after alignment on the ship.

Tolerance for Flatness = ± 0.6 mm ( ± 0.024 inches or ± 0.002 feet)
Tolerance for array cut-out angle of deflection = ± 0.6 mm ( ± 0.024 inches or ± 0.002 feet)

### Reference Marks

Tolerance for offset location of reference marks = ± 1.5 mm ( ± 0.005 feet)
Tolerance for offset location of reference marks on upper decks = ± 3.0 mm ( ± 0.01 feet)

### Draft Marks

Tolerance for location/elevation of draft marks = ± 6.0 mm ( ± 0.02 feet)

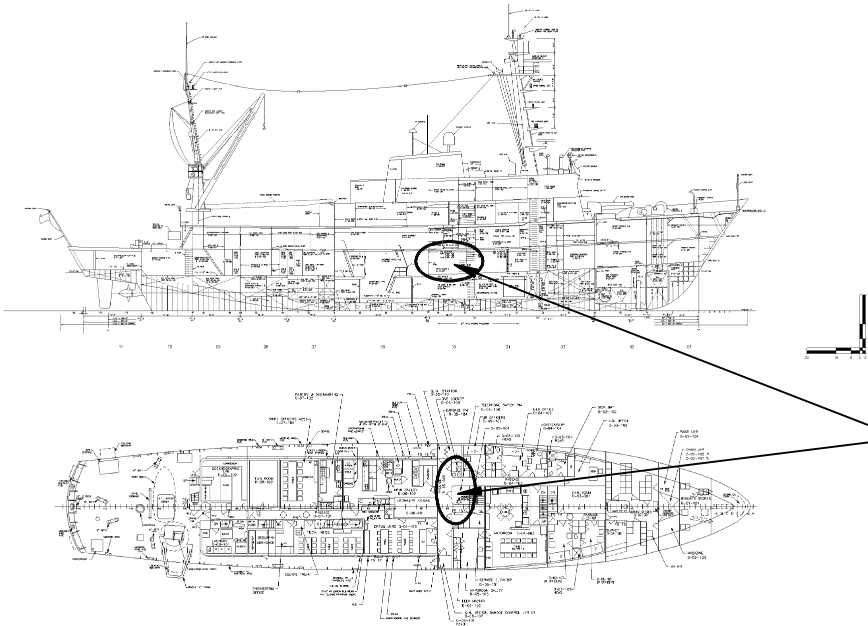
# NOAA Rainier

## APPENDIX: EXHIBITS

Westlake consultants, inc

October 12, 2010

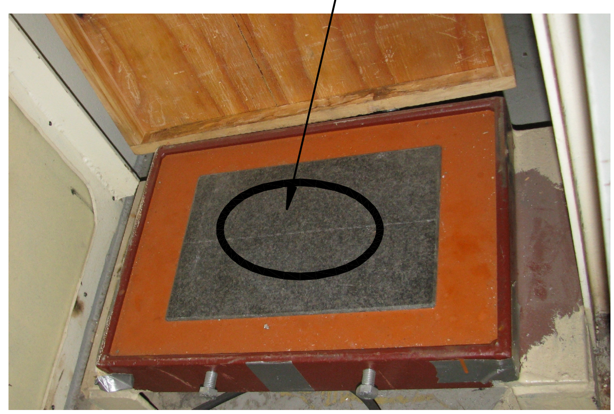
# EXHIBIT # 1



POINT LOCATION ON VESSEL

GRANITE BLOCK IN CLOSET
WCI SURVEY #3005

GRANITE BLOCK
WCI SURVEY #3005



POINT LOCATION: "C" DECK: UNDER STAIRS IN CLOSET, ROOM C5 (CPO LOUNGE)
WCI POINT NUMBER: 3005
GENERAL DESCRIPTION: –

| | | |
|---|---|---|
| WCI REFERENCE NUMBER : | 3005 | |
| X (LONGITUDINAL OFFSET) : | 0.000 M | ( 0.000') |
| Y (TRANSVERSE OFFSET) : | 0.000 M | ( 0.000') |
| Z (BASELINE OFFSET) : | 0.000 M | ( 0.000') |

SURVEY NOTES:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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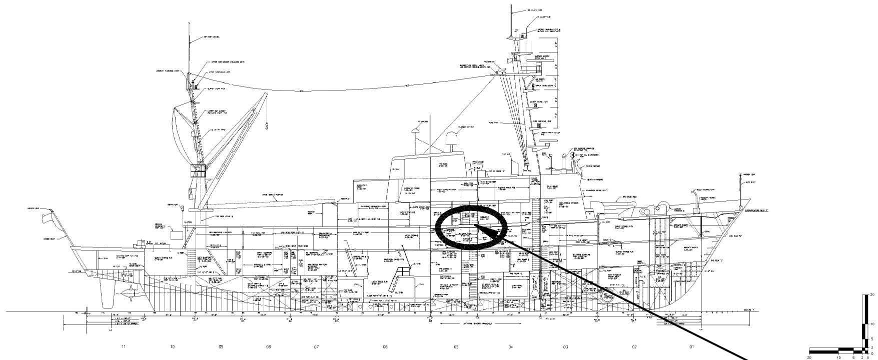
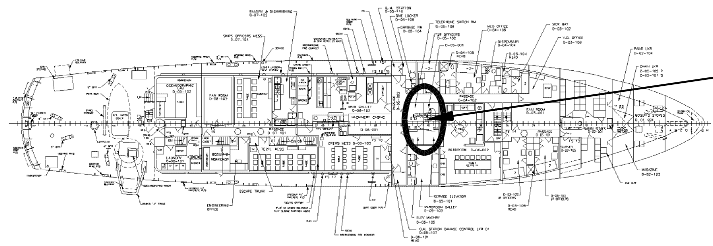
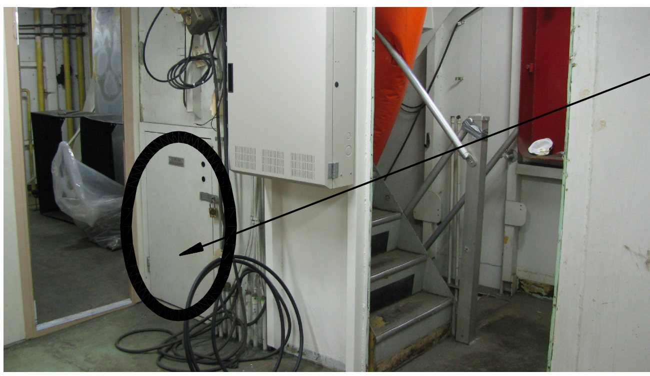
PACIFIC CORPORATE CENTER
15115 S.W. SEQUOIA PARKWAY, SUITE 150 (503) 684-0652
TIGARD, OREGON 97224 FAX (503) 624-0157



# EXHIBIT # 2



POINT LOCATION ON VESSEL



IMU MOUNTING HOLE (℄ PLATE) IN CLOSET
WCI SURVEY #3006

IMU MOUNTING HOLE (℄ PLATE)
WCI SURVEY #3006

POINT LOCATION: "C" DECK: UNDER STAIRS IN CLOSET, ROOM C5 (CPO LOUNGE)
WCI POINT NUMBER: 3006
GENERAL DESCRIPTION: ℄ IMU MOUNTING HOLE ON PLATE IN CLOSET

| | | |
|---|---|---|
| WCI REFERENCE NUMBER : | 3006 | |
| X (LONGITUDINAL OFFSET) : | 0.020 M | ( 0.067') |
| Y (TRANSVERSE OFFSET) : | −0.562 M | (−1.844') |
| Z (BASELINE OFFSET) : | 0.120 M | ( 0.395') |

SURVEY NOTES:
1) COORDINATES BASED ON ORIGIN (0,0,0)
@ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
+X AXIS– FORWARD OF GRANITE BLOCK
+Y AXIS– STBD OF GRANITE BLOCK
+Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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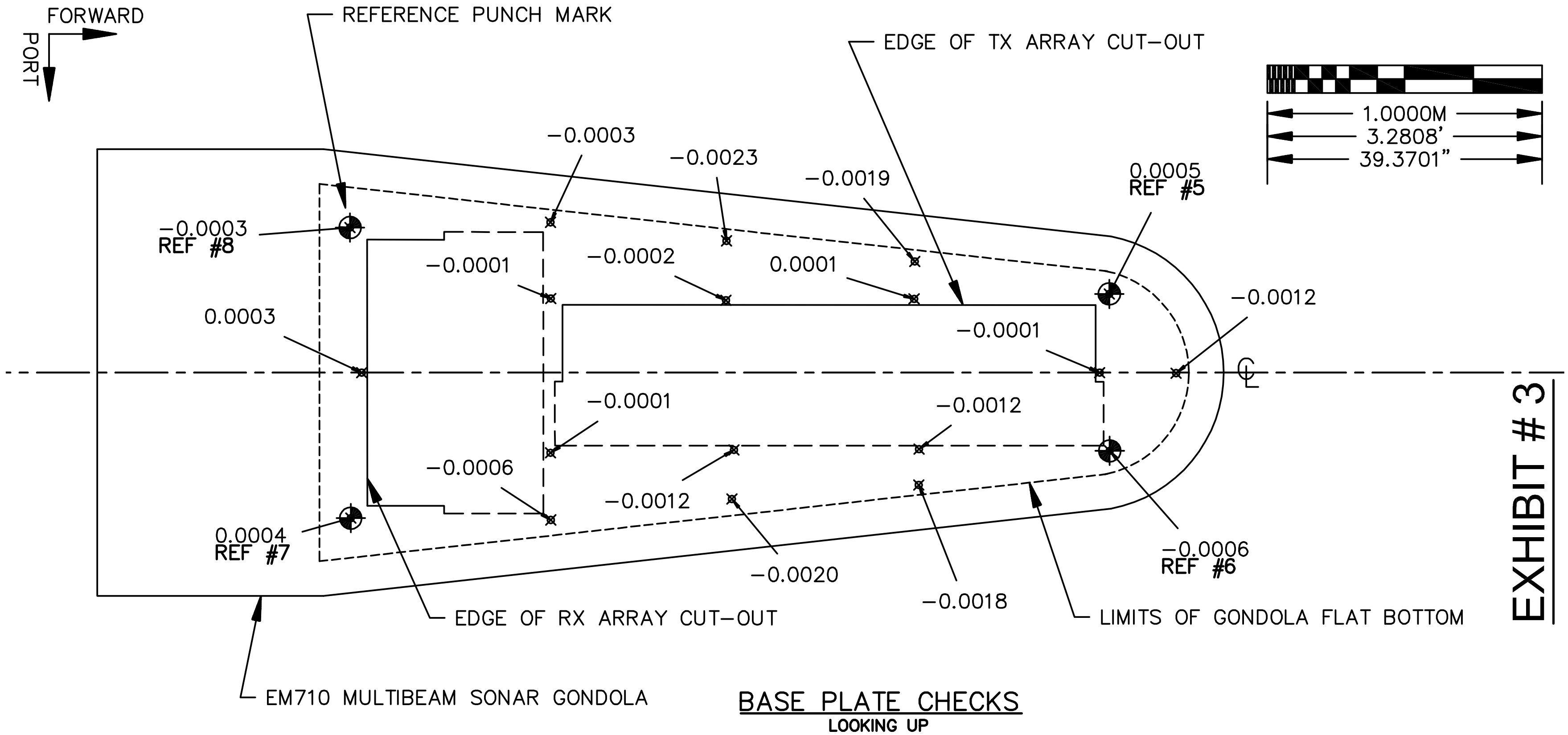
TIGARD, OREGON 97224 FAX (503) 624-0157




# EXHIBIT # 3

## BASE PLATE CHECKS

LOOKING UP

## SURVEY NOTES:

1) SURVEY COMPLETED 06-02-10
2) SOKKIA NET2B INDUSTRIAL THEODOLITE WITH MONMOS TARGETING SYSTEM
3) ALL DISTANCES ARE IN METERS (UNLESS NOTED OTHERWISE)
4) CENTERLINE ESTABLISHED FROM PUNCH MARKS SET BY VIGOR
5) FLAT PLANE ESTABLISHED FROM 'BEST FIT' AVERAGE OF REFERENCE MARKS 5, 6, 7, AND 8. REMAINING SHOTS USED TO VERIFY FLAT BASE PLATE.
6) PLAN VIEW IS LOOKING UP AT GONDOLA BOTTOM
7) POSITIVE NUMBER INDICATES BOTTOM IS ABOVE PLANE WHEN GONDOLA IS INVERTED AND BELOW PLANE WHEN GONDOLA IS IN UPRIGHT POSITION
   NEGATIVE NUMBER INDICATES BOTTOM IS BELOW PLANE WHEN GONDOLA IS INVERTED AND ABOVE PLANE WHEN GONDOLA IS IN UPRIGHT POSITION

## CONVERSIONS:

0.0001M = 0.004"
0.0002M = 0.008"
0.0003M = 0.012"
0.0004M = 0.016"
0.0005M = 0.020"
0.0006M = 0.024"
0.0007M = 0.028"
0.0008M = 0.032"
0.0009M = 0.036"
0.0010M = 0.040"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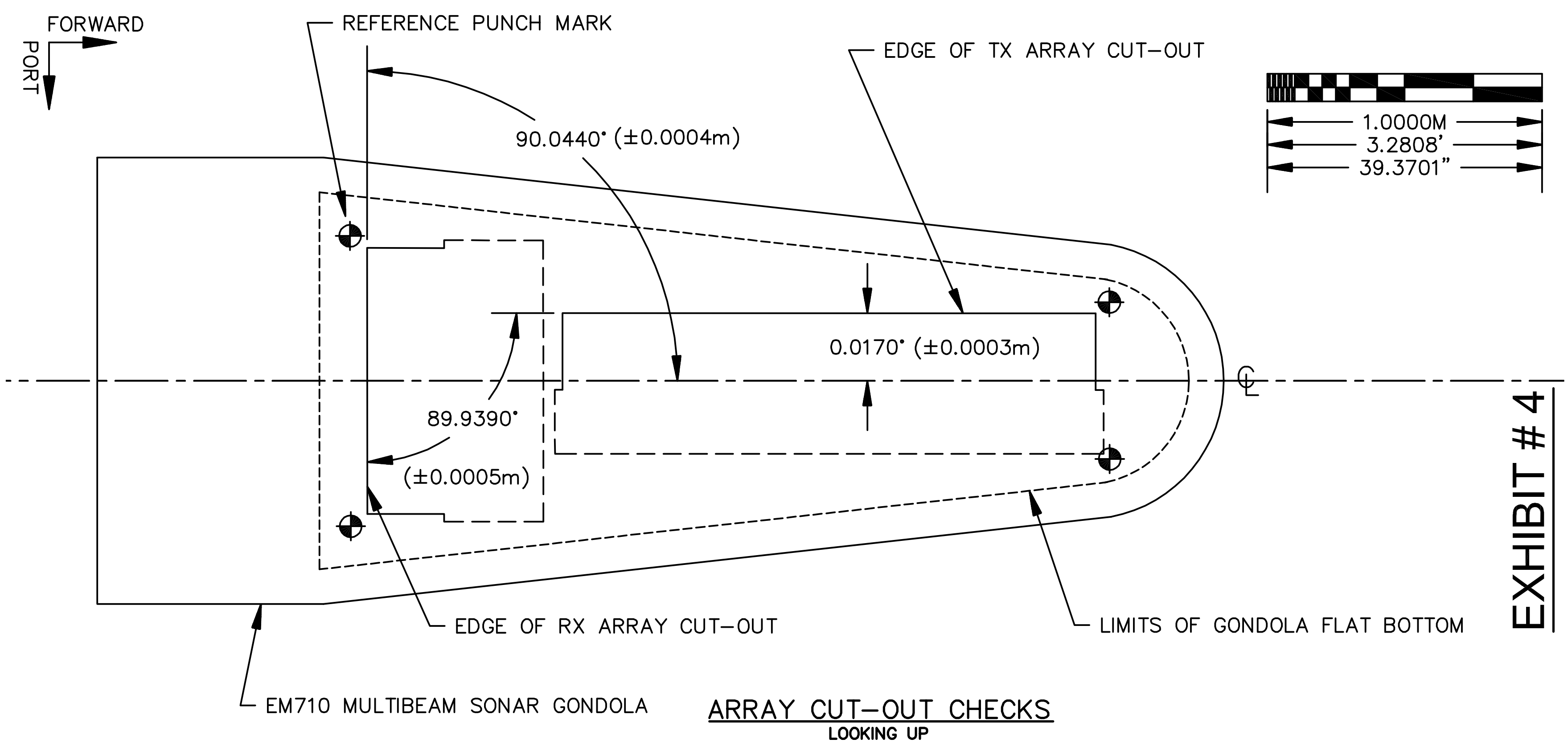
NOAA RAINIER
EM710 MULTIBEAM SONAR GONDOLA
BASE PLATE AND CUT-OUT CHECKS
VIGOR INDUSTRIAL, LLC

| | |
|---|---|
| DATE: | 06-03-10 |
| DWG BY: | CRB2 |
| CHK BY: | DDL |
| SCALE: | N/A |
| SIZE: | 11"X17" |
| DWG: | 2187021.DWG |
| JOB NO: | 2187-02 |
| REV #: | N/A |
| SHEET: | 1 OF 2 |




# EXHIBIT # 4

## ARRAY CUT-OUT CHECKS
LOOKING UP

## CONVERSIONS:

0.0001M = 0.004"
0.0002M = 0.008"
0.0003M = 0.012"
0.0004M = 0.016"
0.0005M = 0.020"
0.0006M = 0.024"
0.0007M = 0.028"
0.0008M = 0.032"
0.0009M = 0.036"
0.0010M = 0.040"

## SURVEY NOTES:

1) SURVEY COMPLETED 06-02-10
2) SOKKIA NET2B INDUSTRIAL THEODOLITE WITH MONMOS TARGETING SYSTEM
3) ALL DISTANCES ARE IN METERS (UNLESS NOTED OTHERWISE)
4) CENTERLINE ESTABLISHED FROM PUNCH MARKS SET BY VIGOR
5) ANGULAR DEFLECTION IS DECIMAL DEGREES, DIMENSIONAL DEFLECTION IS METERS.
6) PLAN VIEW IS LOOKING UP AT GONDOLA BOTTOM

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NOAA RAINIER
EM710 MULTIBEAM SONAR GONDOLA
BASE PLATE AND CUT-OUT CHECKS
VIGOR INDUSTRIAL, LLC

| | |
|---|---|
| DATE: | 06-03-10 |
| DWG BY: | CRB2 |
| CHK BY: | DDL |
| SCALE: | N/A |
| SIZE: | 11"X17" |
| DWG: | 218702I.DWG |
| JOB NO: | 2187-02 |
| REV #: | N/A |
| SHEET: | 2 OF 2 |

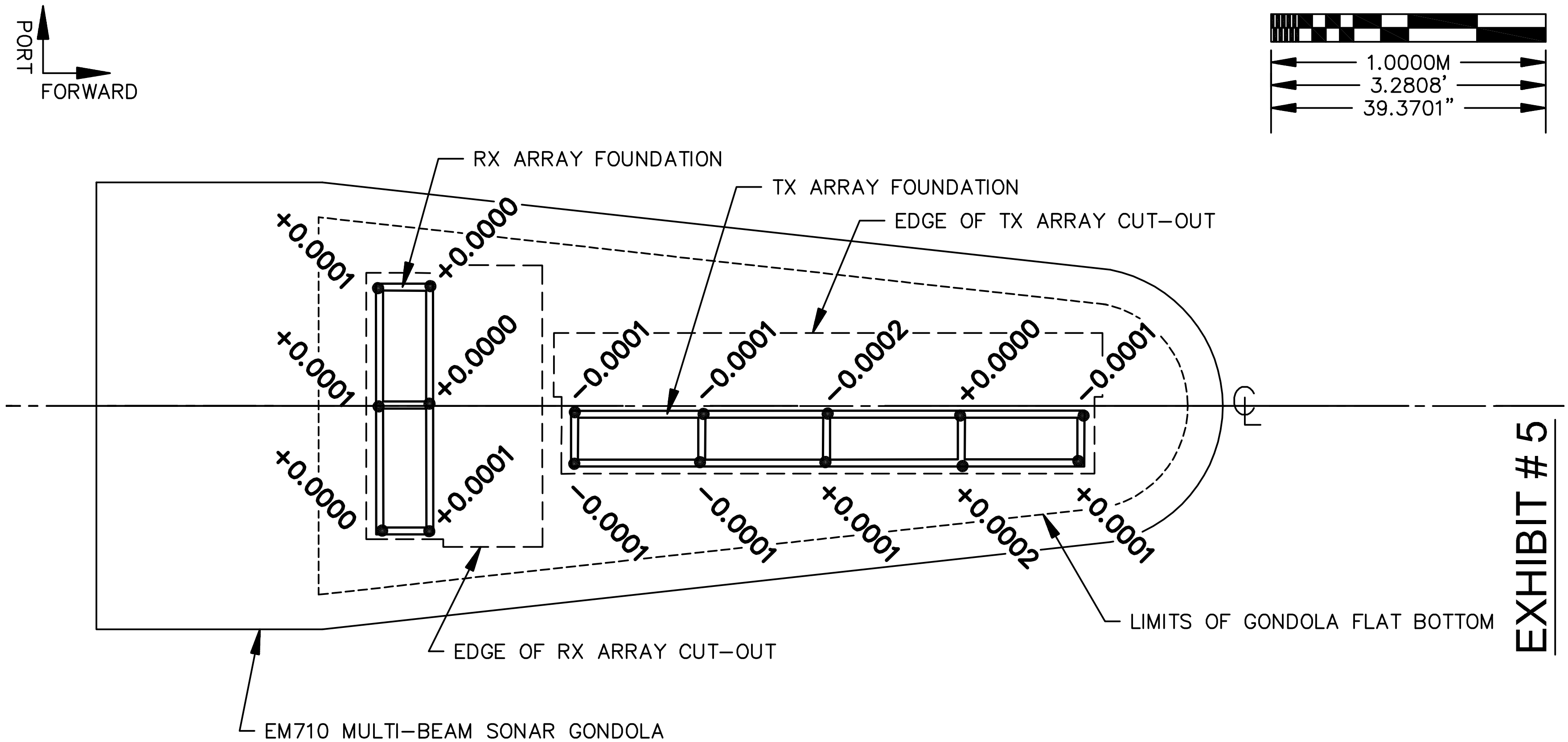


EXHIBIT # 5

## MULTI-BEAM FOUNDATION PLANE CHECKS

LOOKING DOWN

### SURVEY NOTES:

1) SURVEY COMPLETED 08-17-10
2) SOKKIA NET2B INDUSTRIAL THEODOLITE WITH MONMOS TARGETING SYSTEM
3) ALL DISTANCES ARE IN METERS (UNLESS NOTED OTHERWISE)
4) FLAT PLANE ESTABLISHED FROM 'BEST FIT' OF ALL SHOTS AT BOLT LOCATIONS.
5) PLAN VIEW IS LOOKING DOWN AT MULTI-BEAM FOUNDATION
6) POSITIVE NUMBER INDICATES FOUNDATION NEEDS TO BE RAISED TO FALL ON BEST FIT FLAT PLANE
   NEGATIVE NUMBER INDICATES FOUNDATION NEEDS TO BE LOWERED TO FALL ON BEST FIT FLAT PLANE.
7) TOLERANCE TO PLANE (PER KONGSBERG) IS ± 0.0002M

### CONVERSIONS:

0.0001M = 0.004"
0.0002M = 0.008"
0.0003M = 0.012"

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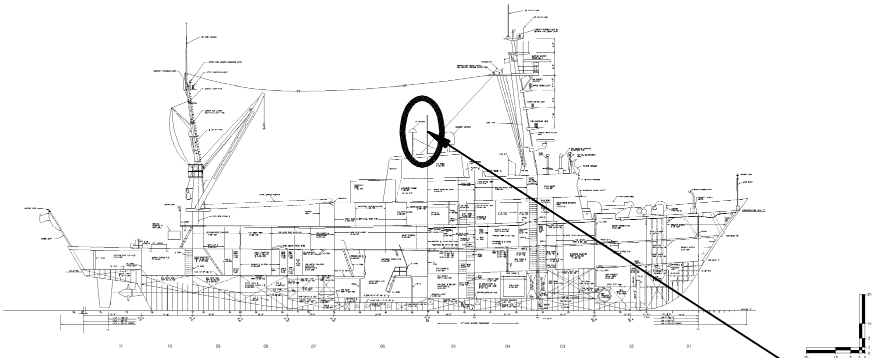
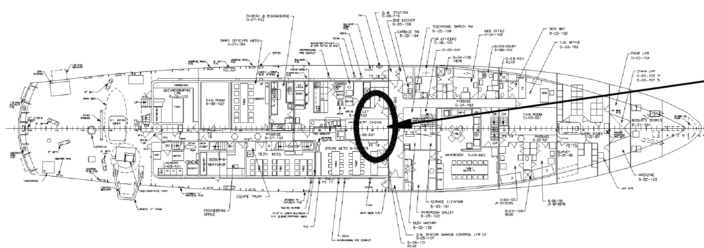
NOAA RAINIER
EM710 MULTI-BEAM SONAR
FOUNDATION CHECKS
VIGOR INDUSTRIAL, LLC

| | |
|---|---|
| DATE: | 08-17-10 |
| DWG BY: | CRB2 |
| CHK BY: | DDL |
| SCALE: | N/A |
| SIZE: | 11"X17" |
| DWG: | 2187021.DWG |
| JOB NO: | 2187-02(-) |
| REV #: | N/A |
| SHEET: | 1 OF 1 |



# EXHIBIT # 6



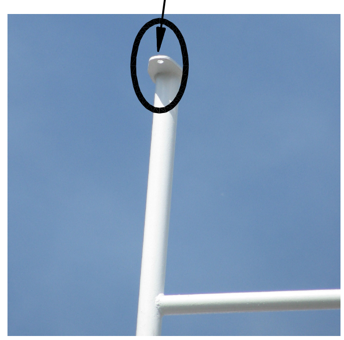
POINT LOCATION ON VESSEL

POS/MV ANTENNA
STBD MOUNT
WCI SURVEY #3007

POS/MV ANTENNA
PORT MOUNT
WCI SURVEY #3008

POS/MV ANTENNA
STBD MOUNT
WCI SURVEY #3007

POS/MV ANTENNA
PORT MOUNT
WCI SURVEY #3008



POINT LOCATION: MID SHIP ABOVE FAN ROOM ON ANTENNA MASTS
WCI POINT NUMBER: 3007, 3008
GENERAL DESCRIPTION: TOP ℄ OF POS/MV ANTENNA MOUNTING HOLES

| WCI REFERENCE NUMBER : | 3007 STBD | | 3008 PORT | |
|---|---|---|---|---|
| X (LONGITUDINAL OFFSET) : | −12.000 M | (−39.369') | −12.026 M | (−39.454') |
| Y (TRANSVERSE OFFSET) : | 2.107 M | (6.913') | 0.112 M | (3.68') |
| Z (BASELINE OFFSET) : | −13.212 M | (−43.348') | −13.200 M | (−43.307') |

<u>SURVEY NOTES</u>:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS: +X AXIS– FORWARD OF GRANITE BLOCK, +Y AXIS– STBD OF GRANITE BLOCK, +Z AXIS– BELOW GRANITE BLOCK

## NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |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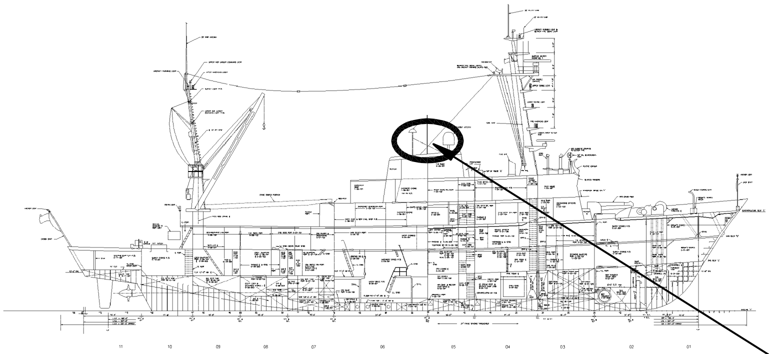

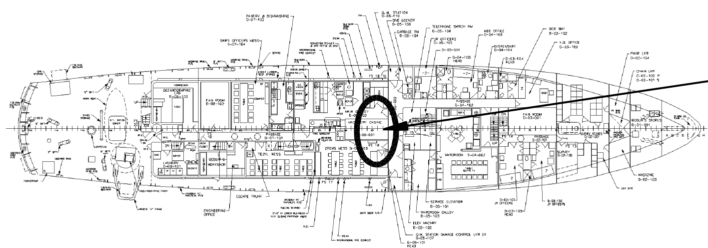

# EXHIBIT # 7

POINT LOCATION ON VESSEL

FLYING BRIDGE BOLT ℄
WCI SURVEY #604

FLYING BRIDGE BOLT ℄
WCI SURVEY #604

POINT LOCATION: MIDSHIP, AFT ON HANDRAIL
WCI POINT NUMBER: 604
GENERAL DESCRIPTION: PUNCH ℄ BOLT ON HANDRAIL

| | | | |
|---|---|---|---|
| WCI REFERENCE NUMBER : | 604 | | |
| X (LONGITUDINAL OFFSET) : | 1.117 | M | ( 3.665') |
| Y (TRANSVERSE OFFSET) : | −11.956 | M | (−39.224') |
| Z (BASELINE OFFSET) : | −10.648 | M | (−34.935') |

SURVEY NOTES:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

## NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |


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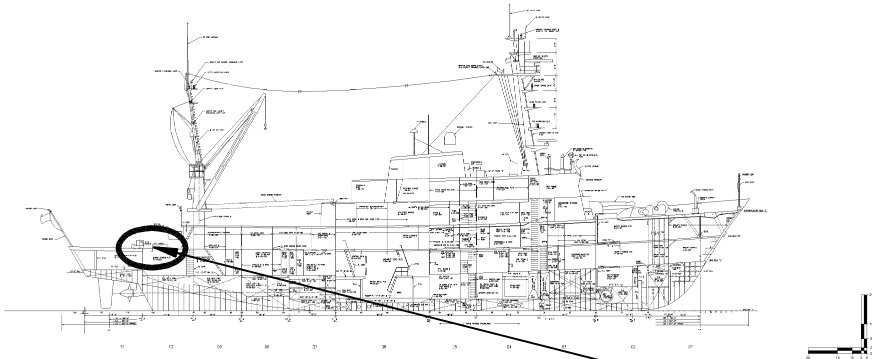
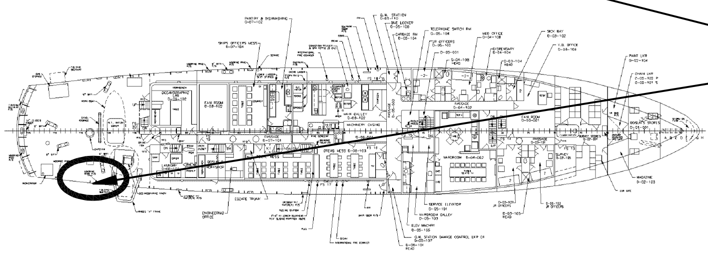
TIGARD, OREGON 97224 FAX (503) 624-0157

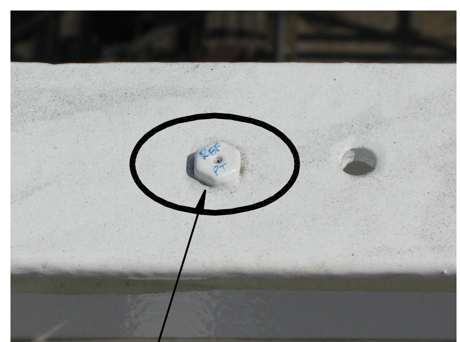
EXHIBIT # 8





POINT LOCATION ON VESSEL

BOLT WITH PUNCH
WCI SURVEY #614



BOLT WITH PUNCH
WCI SURVEY #614

| | |
|---|---|
| POINT LOCATION: | "D" DECK STBD AFT GUNNEL |
| WCI POINT NUMBER: | 614 |
| GENERAL DESCRIPTION: | BOLT WITH PUNCH SET ON TOP OF GUNNEL |

| | | |
|---|---|---|
| WCI REFERENCE NUMBER : | 614 | |
| X (LONGITUDINAL OFFSET) : | 6.591 M | ( 21.624') |
| Y (TRANSVERSE OFFSET) : | −33.005 M | (−108.284') |
| Z (BASELINE OFFSET) : | −3.359 M | (−11.019') |

SURVEY NOTES:
1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
- +X AXIS– FORWARD OF GRANITE BLOCK
- +Y AXIS– STBD OF GRANITE BLOCK
- +Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–07–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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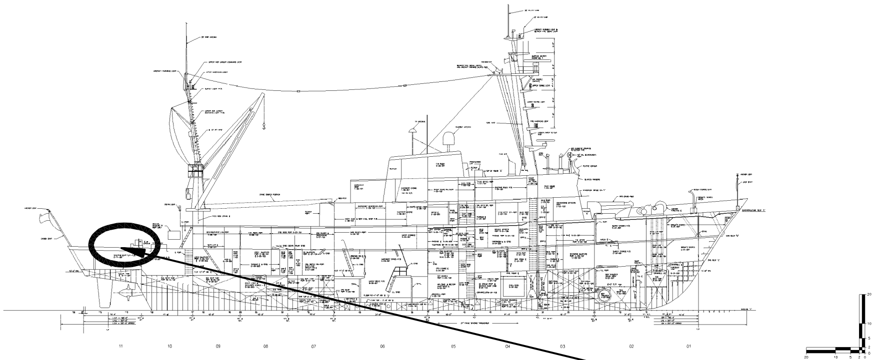
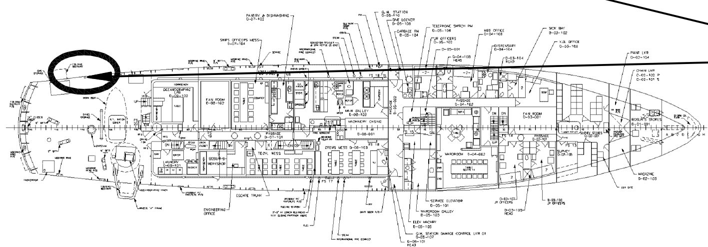
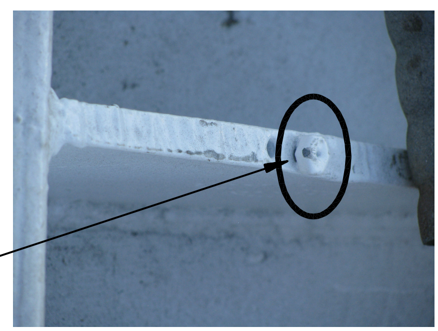
# EXHIBIT # 9





POINT LOCATION ON VESSEL

BOLT SET WITH PUNCH
WCI SURVEY #611



BOLT SET WITH PUNCH
WCI SURVEY #611

POINT LOCATION: "D" DECK ON PORT ANCHOR CHOCK AT STERN
WCI POINT NUMBER: 611
GENERAL DESCRIPTION: BOLT WITH PUNCH SET ON ANCHOR CHOCK

| | | | |
|---|---|---|---|
| WCI REFERENCE NUMBER : | 611 | | |
| X (LONGITUDINAL OFFSET) : | −4.115 | M | (−13.500') |
| Y (TRANSVERSE OFFSET) : | −33.802 | M | (−110.898') |
| Z (BASELINE OFFSET) : | −3.266 | M | (−10.714') |

SURVEY NOTES:
1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

## NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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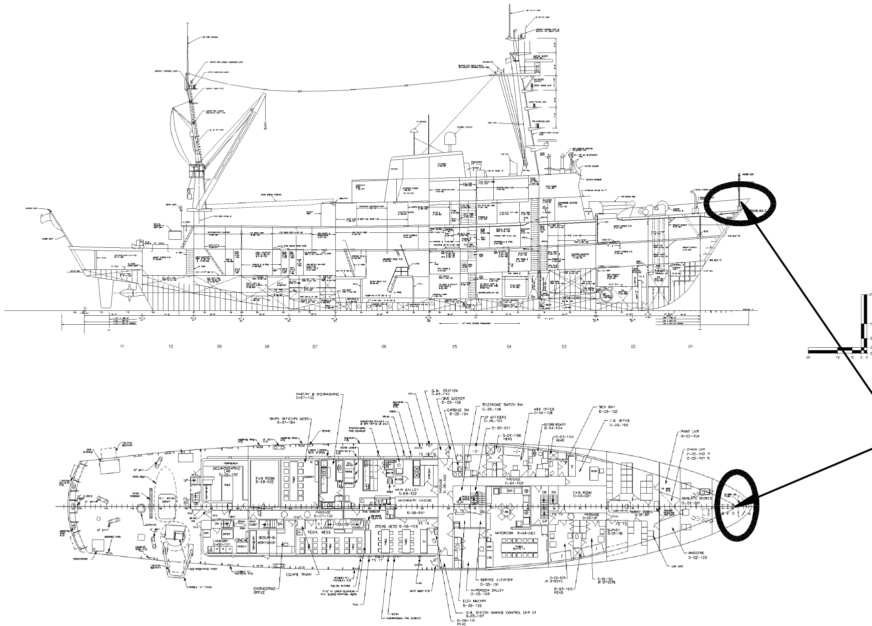
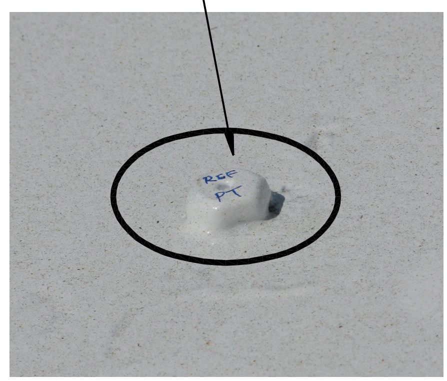
# EXHIBIT # 10



POINT LOCATION ON VESSEL

BOLT WITH PUNCH
WCI SURVEY #591




BOLT WITH PUNCH
WCI SURVEY #591

POINT LOCATION: "E" DECK, FORWARD OF JACK STAFF ON ℄
WCI POINT NUMBER: 591
GENERAL DESCRIPTION: BOLT WITH PUNCH SET FORWARD OF JACK STAFF

| | | |
|---|---|---|
| WCI REFERENCE NUMBER : | 591 | |
| X (LONGITUDINAL OFFSET) : | 1.200 M | ( 3.936') |
| Y (TRANSVERSE OFFSET) : | 28.474 M | ( 93.418') |
| Z (BASELINE OFFSET) : | −7.726 M | (−25.347') |

SURVEY NOTES:
1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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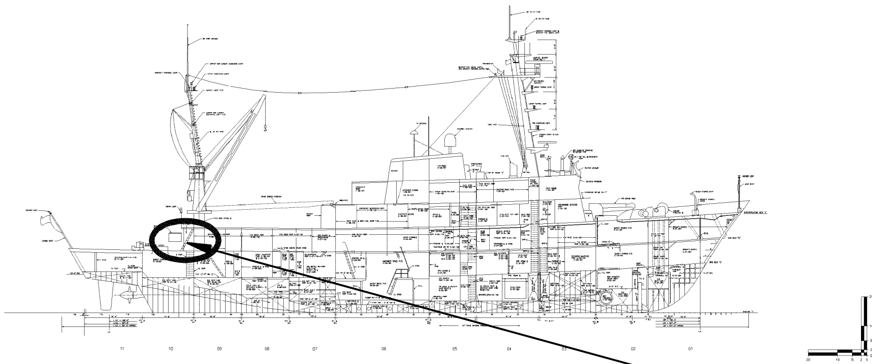
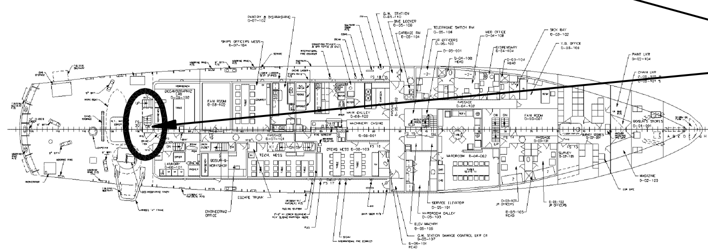
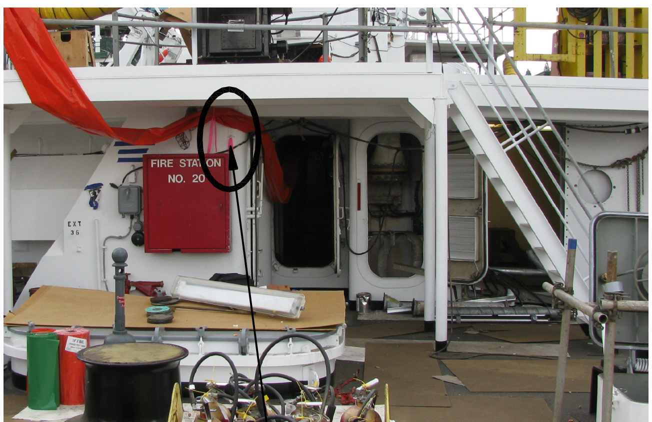
EXHIBIT # 11



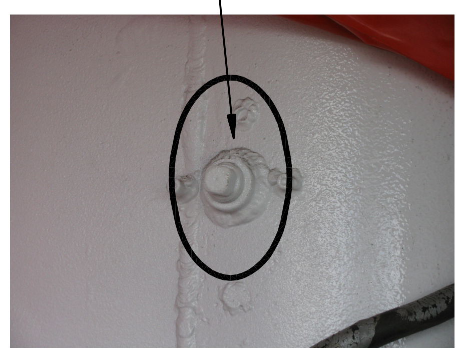


POINT LOCATION ON VESSEL

BOLT WITH PUNCH
WCI SURVEY #613




BOLT WITH PUNCH
WCI SURVEY #613



POINT LOCATION: "D" DECK, STERN BULKHEAD
WCI POINT NUMBER: 613
GENERAL DESCRIPTION: BOLT WITH PUNCH SET ON AFT FACE OF STERN BULKHEAD

| | | | |
|---|---|---|---|
| WCI REFERENCE NUMBER : | 613 | | |
| X (LONGITUDINAL OFFSET) : | 1.332 | M | ( 4.370') |
| Y (TRANSVERSE OFFSET) : | −28.592 | M | (−93.806') |
| Z (BASELINE OFFSET) : | −4.296 | M | (−14.095') |

SURVEY NOTES:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |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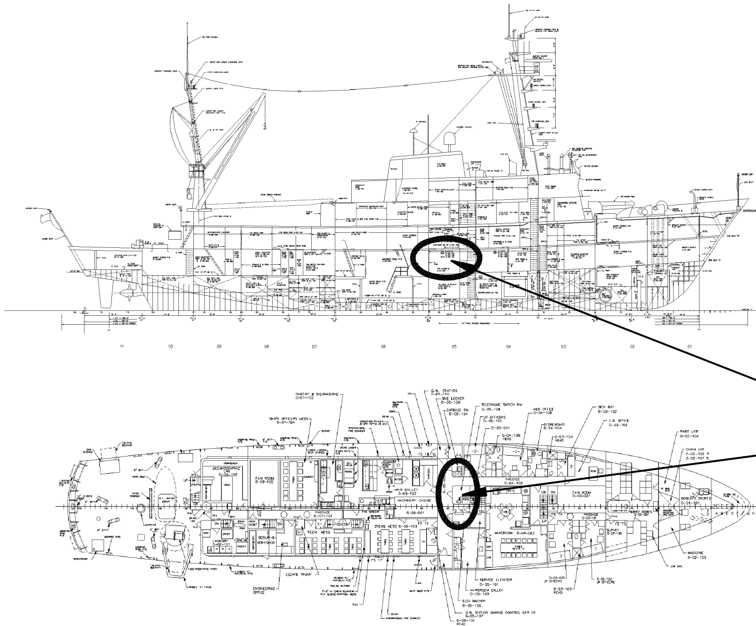
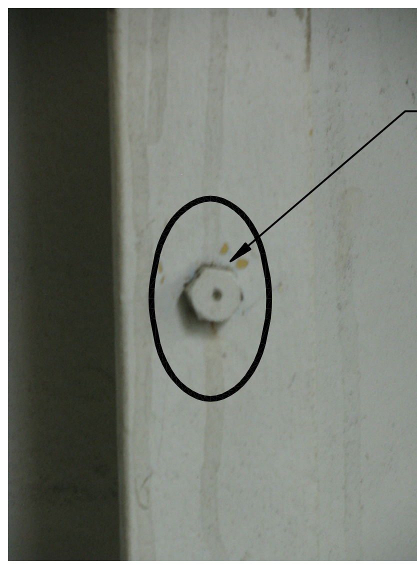


POINT LOCATION ON VESSEL

# EXHIBIT # 12

BOLT WITH PUNCH
WCI SURVEY #472



BOLT WITH PUNCH
WCI SURVEY #472

POINT LOCATION: AFT EXTERIOR WALL OF IMU CLOSET CPO LOUNGE IN ROOM C5
WCI POINT NUMBER: 472
GENERAL DESCRIPTION: BOLT WITH PUNCH ON AFT EXTERIOR WALL

| | | |
|---|---|---|
| WCI REFERENCE NUMBER : | 472 | |
| X (LONGITUDINAL OFFSET) : | −0.359 M | (−1.177') |
| Y (TRANSVERSE OFFSET) : | −0.428 M | (−1.403') |
| Z (BASELINE OFFSET) : | −1.202 M | (−3.943) |

SURVEY NOTES:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS:
   +X AXIS– FORWARD OF GRANITE BLOCK
   +Y AXIS– STBD OF GRANITE BLOCK
   +Z AXIS– BELOW GRANITE BLOCK

## NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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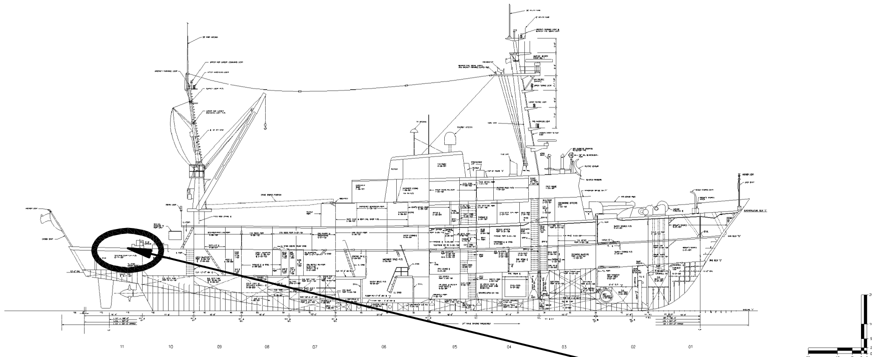
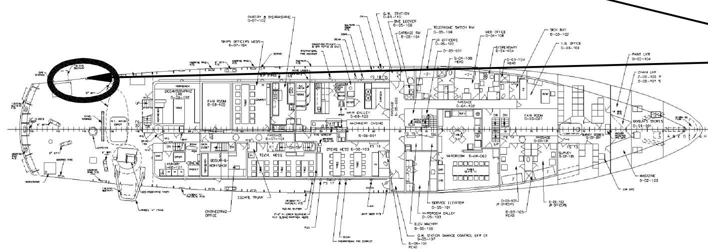
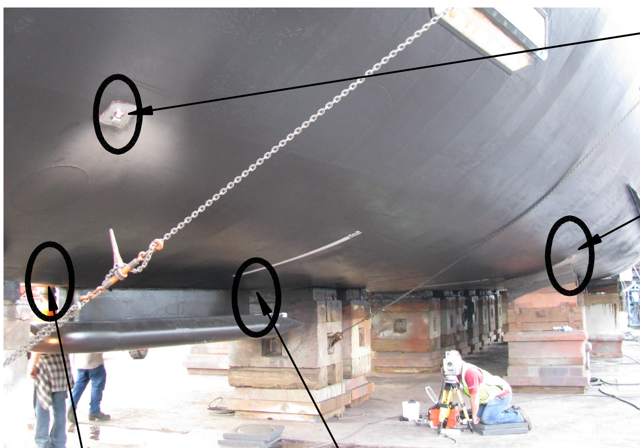
# EXHIBIT # 13





POINT LOCATION ON VESSEL

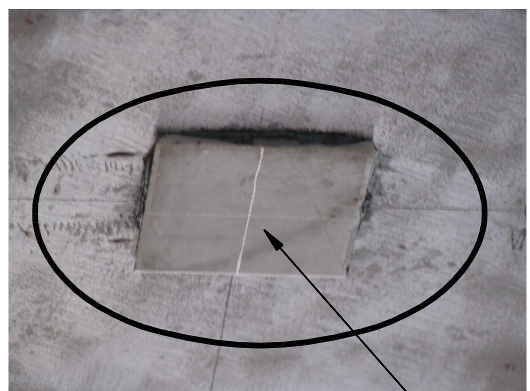


SS PLATE
WCI SURVEY #555

SS PLATE
WCI SURVEY #556

SS PLATE
WCI SURVEY #553

SS PLATE
WCI SURVEY #554



2"X2" STAINLESS STEEL PLATE
WITH "X" AND PUNCH @ ℄
(TYPICAL)

POINT LOCATION: BOTTOM OF SHIP, PORT SIDE NEAR SIMRAD GONDOLA
WCI POINT NUMBER: 553, 554, 555, 556
GENERAL DESCRIPTION: 2"x2" STAINLESS STEEL PLATES

| WCI REFERENCE NUMBER : | 553 | 554 | 555 | 556 |
|---|---|---|---|---|
| X (LONGITUDINAL OFFSET) : | 5.231 M (17.160') | 9.689 M (31.787') | 11.165 M (36.632') | 1.256 M (4.120') |
| Y (TRANSVERSE OFFSET) : | 1.192 M (3.909') | 1.192 M (3.910') | −0.824 M (−2.702') | −2.825 M (−9.267') |
| Z (BASELINE OFFSET) : | 3.981 M (13.062') | 3.969 M (13.023') | 3.061 M (10.043') | 3.525 M (11.565') |

SURVEY NOTES:

1) COORDINATES BASED ON ORIGIN (0,0,0) @ ℄ TOP FACE OF GRANITE BLOCK
2) X,Y,Z AXIS ALIGNMENT AS FOLLOWS: +X AXIS– FORWARD OF GRANITE BLOCK, +Y AXIS– STBD OF GRANITE BLOCK, +Z AXIS– BELOW GRANITE BLOCK

NOAA RAINIER

SHIP SURVEY, SEPTEMBER 2010
COMPLETED AT CASCADE GENERAL SHIPYARD
PORTLAND OREGON

DWG: 218702i.DWG

| | |
|---|---|
| DATE: | 10–12–10 |
| DWG BY: | PPR |
| CHK BY: | CRB2 |
| SCALE: | NTS |
| REV #: | N/A |
| JOB NO: | 2187–02 |

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# NOAA Rainier

## END OF REPORT

Westlake consultants, inc

October 12, 2010

# Dynamic Draft

# 2801 Dynamic Draft
# SYSTEM READINESS REPORT 2011

**Vessel:** RA-4; Hull # 2801
**Sonar:** Reson 7125
**Written By:** CST Jacobson
**Report Date:** 5/2/2011

## Background:

Dynamic draft is the vertical displacement due to the combined effects of settlement and squat. The Field Procedures Manual requires settlement and squat to be measured at least once annually for each vessel.

## Calibration Location, Date, and Personnel:

The dynamic draft determination was performed in Lake Washington, WA.

**Personnel**: SST Gendron, AST Cruz
**Coxwain**: SS Allen
**Location**: Lake Washington, WA
**Date**: 4/15/2011; DN 115

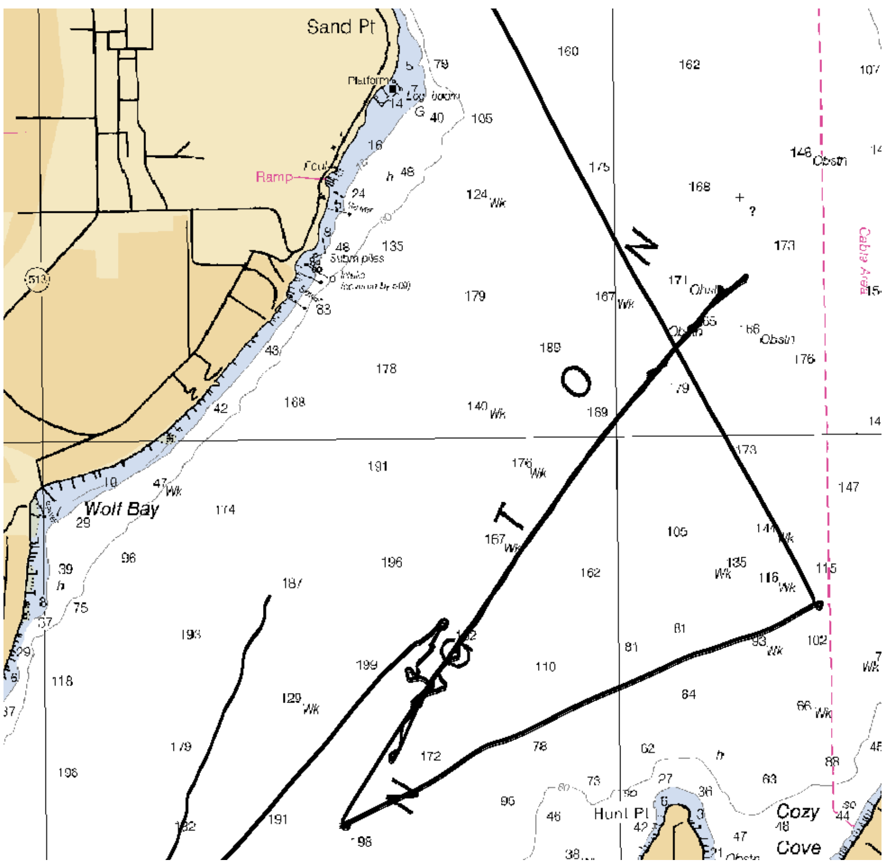



*Figure 1: Location of line for the Ellipsoid Reference Method, Chart 18447*

## Procedure for the Ellipsoidal Referenced Method:

The Ellipsoidally Referenced Dynamic Draft Measurement (ERDDM) methodology as outline in section 1.4.2.1.2.1 [Post-Processed Kinematic (PPK) GPS] of the Field Procedures Manual was used by *Rainier* to determine the settlement and squat values of her survey launches

For data acquisition, the launch was run on a constant heading line and speed was increased in two-knot increments from four to 10 knots at two-minute intervals during the line. A two minute rest period was placed between the runs. POSPac data recording began shortly after leaving the pier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by *Rainier*.

## Results and Final Error Estimates:

SST Gendron compiled the results from the data following the acquisition of the POS data. The POSPac data recorded by the POS MV was imported into the POSPac MMS software suite and processed using Smart Base processing. The data from the CORS stations SEAI, SEAT, PUPU, PFLD, and P426 were selected as the reference stations.

The resulting SBET was exported as an ASCII file, which was processed using the Pydro macro ProcSBETDynamicDraft.py. The resulting dynamic draft curve and table is shown below. Values generated using this method were compared to historic values and correlated well, with the ERDDM giving a more complete dynamic draft curve.

| Speed [m/s] | Delta Draft [m] |
|---|---|
| 0.00 | 0.00 |
| 0.50 | -0.01 |
| 1.00 | -0.01 |
| 1.50 | -0.00 |
| 2.00 | 0.01 |
| 2.50 | 0.03 |
| 3.00 | 0.04 |
| 3.50 | 0.05 |
| 4.00 | 0.05 |
| 4.50 | 0.04 |
| 5.00 | 0.01 |
| 5.50 | -0.02 |
| 6.00 | -0.05 |
| 6.50 | -0.10 |
| 7.00 | -0.14 |
| 7.50 | -0.18 |
| 8.00 | -0.22 |
| 8.50 | -0.25 |
| 9.00 | -0.26 |
| 9.50 | -0.24 |
| 10.00 | -0.19 |

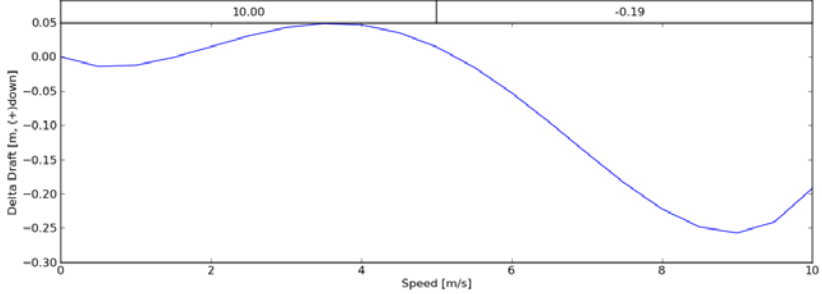



*Figure 2: Dynamic Draft Curve and Values Table Generated using the ERDDM Method*

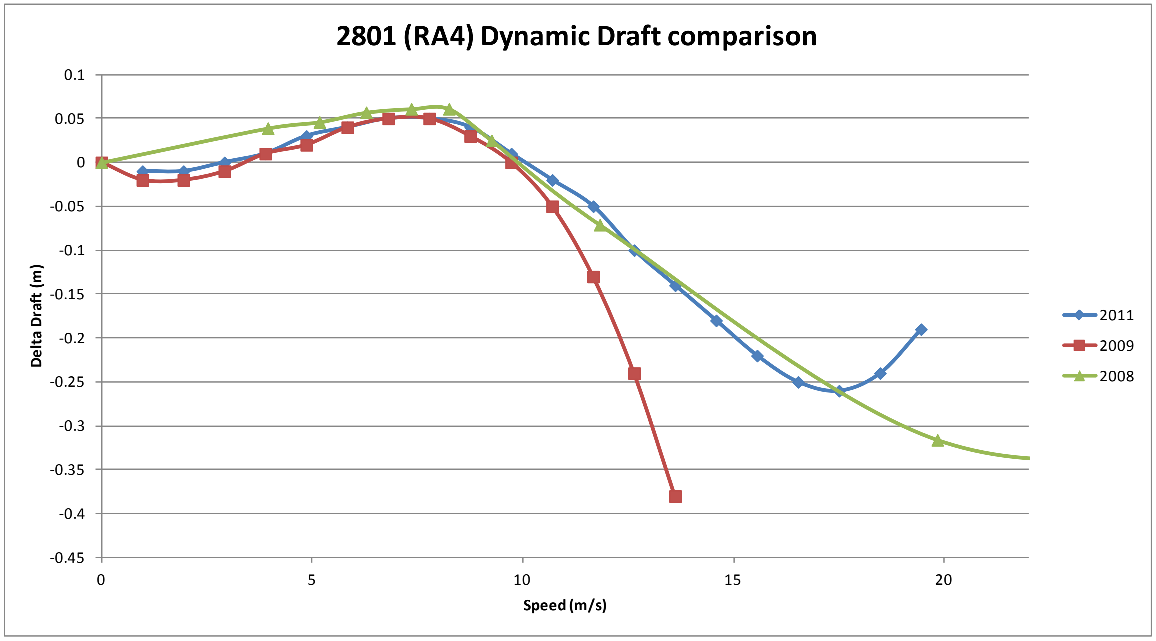



*Figure 3: Dynamic Draft Curve Comparison*

## Recommendations

It is the recommendation that the values generated using the ERDDM processing procedure in POSPac be used as the Dynamic Draft calibration for Vessel 2801. The data should be accepted, and the values calculated supersede prior values for the upcoming hydrographic season of 2011.

# 2802 Dynamic Draft
# SYSTEM READINESS REPORT 2011

**Vessel:** RA-5; Hull # 2802
**Sonar:** Reson 7125
**Written By:** CST Jacobson
**Report Date:** 5/2/2011

## Background:

Dynamic draft is the vertical displacement due to the combined effects of settlement and squat. The Field Procedures Manual requires settlement and squat to be measured at least once annually for each vessel.

## Calibration Location, Date, and Personnel:

The dynamic draft determination was performed in Lake Washington, WA.

**Personnel**: ST Wilson, ENS Buesseler
**Coxwain**: SS Foye
**Location**: Lake Washington, WA
**Date**: 4/25/2011; DN 115

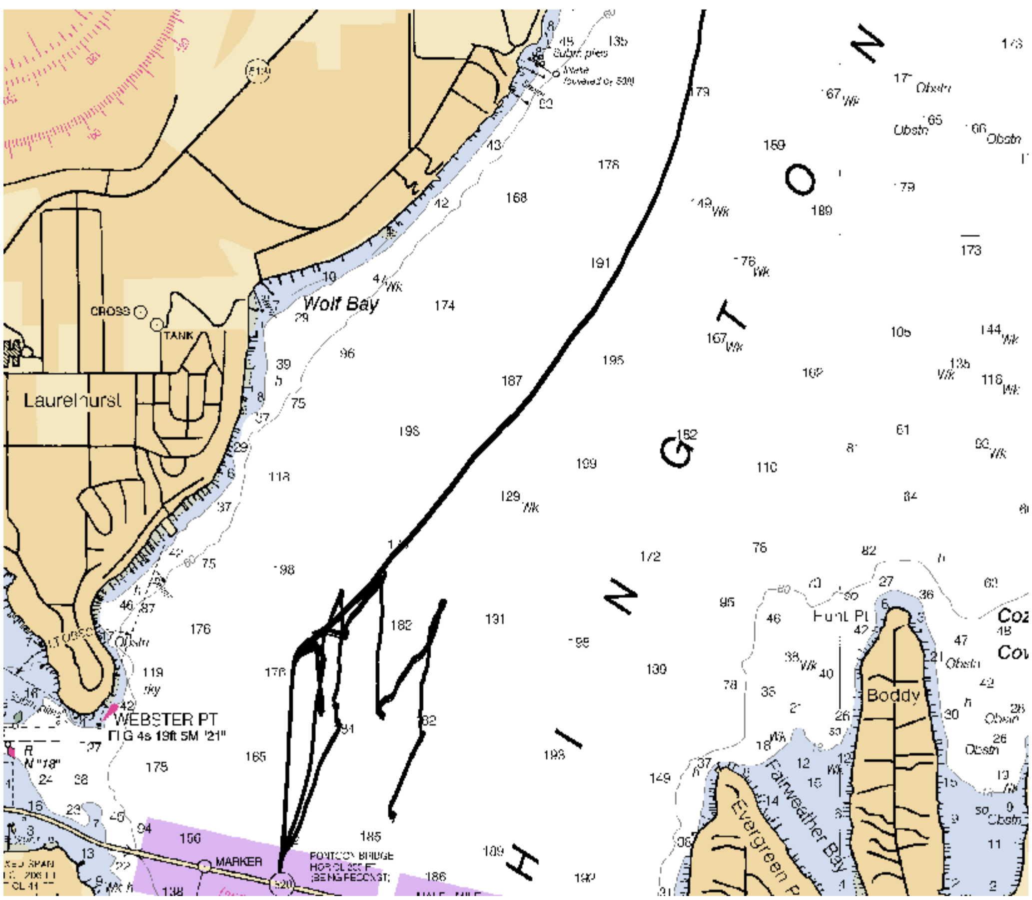



*Figure 1: Location of line for the Ellipsoid Reference Method, Chart 18447*

## Procedure for the Ellipsoidal Referenced Method:

The Ellipsoidally Referenced Dynamic Draft Measurement (ERDDM) methodology as outline in section 1.4.2.1.2.1 [Post-Processed Kinematic (PPK) GPS] of the Field Procedures Manual was used by *Rainier* to determine the settlement and squat values of her survey launches

For data acquisition, the launch was run on a constant heading line and speed was increased in two-knot increments from four to 10 knots at two-minute intervals during the line. A two minute rest period was placed between the runs. POSPac data recording began shortly after leaving the pier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by *Rainier*.

## Results and Final Error Estimates:

SST Gendron compiled the results from the data following the acquisition of the POS data. The POSPac data recorded by the POS MV was imported into the POSPac MMS software suite and processed using Smart Base processing. The data from the CORS stations SEAI, SEAT, PUPU, PRDY, PFLD, and P426 were selected as the reference stations.

The resulting SBET was exported as an ASCII file, which was processed using the Pydro macro ProcSBETDynamicDraft.py. The resulting dynamic draft curve and table is shown below. Values generated using this method were compared to historic values and correlated well, with the ERDDM giving a more complete dynamic draft curve.

| | |
|---|---|
| 3.50 | 0.06 |
| 4.00 | 0.05 |
| 4.50 | 0.04 |
| 5.00 | 0.02 |
| 5.50 | -0.01 |
| 6.00 | -0.05 |
| 6.50 | -0.09 |
| 7.00 | -0.15 |
| 7.50 | -0.20 |
| 8.00 | -0.27 |
| 8.50 | -0.33 |
| 9.00 | -0.40 |
| 9.50 | -0.46 |
| 10.00 | -0.52 |
| 10.50 | -0.57 |
| 11.00 | -0.61 |
| 11.50 | -0.63 |
| 12.00 | -0.63 |
| 12.50 | -0.61 |
| 13.00 | -0.57 |
| 13.50 | -0.48 |
| 14.00 | -0.36 |

$+0.000223*X^4 -0.00453*X^3 +0.0179*X^2 -0.000778*X$

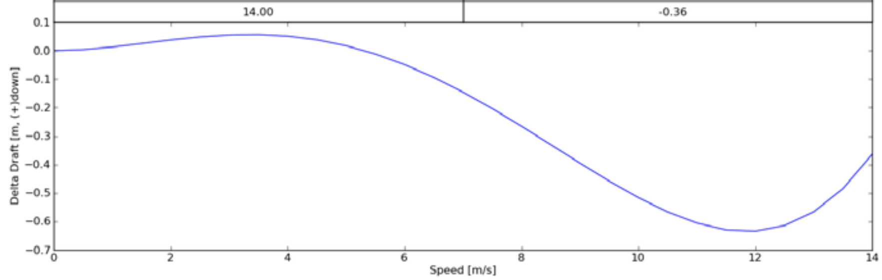



*Figure 2: Dynamic Draft Curve and Values Table Generated using the ERDDM Method*

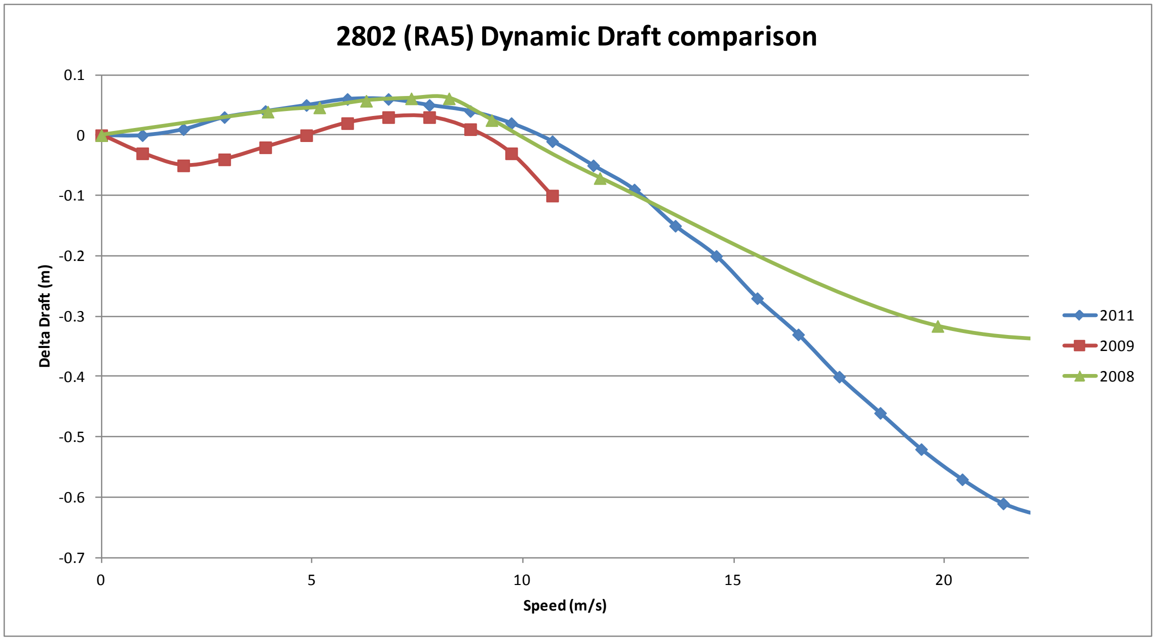



*Figure 3: Dynamic Draft Curve Comparison*

## Recommendations

It is the recommendation that the values generated using the ERDDM processing procedure in POSPac be used as the Dynamic Draft calibration for Vessel 2802. The data should be accepted, and the values calculated supersede prior values for the upcoming hydrographic season of 2011.

# 2803 Dynamic Draft
# SYSTEM READINESS REPORT 2011

**Vessel:** RA-3; Hull # 2803
**Sonar:** Reson 7125
**Written By:** CST Jacobson
**Report Date:** 5/2/2011

## Background:

Dynamic draft is the vertical displacement due to the combined effects of settlement and squat. The Field Procedures Manual requires settlement and squat to be measured at least once annually for each vessel.

## Calibration Location, Date, and Personnel:

The dynamic draft determination was performed in Lake Washington, WA.

**Personnel**: LT SST Gendron, AST Cruz
**Coxwain**: SS Allen
**Location**: Lake Washington, WA
**Date**: 4/27/2011; DN 117

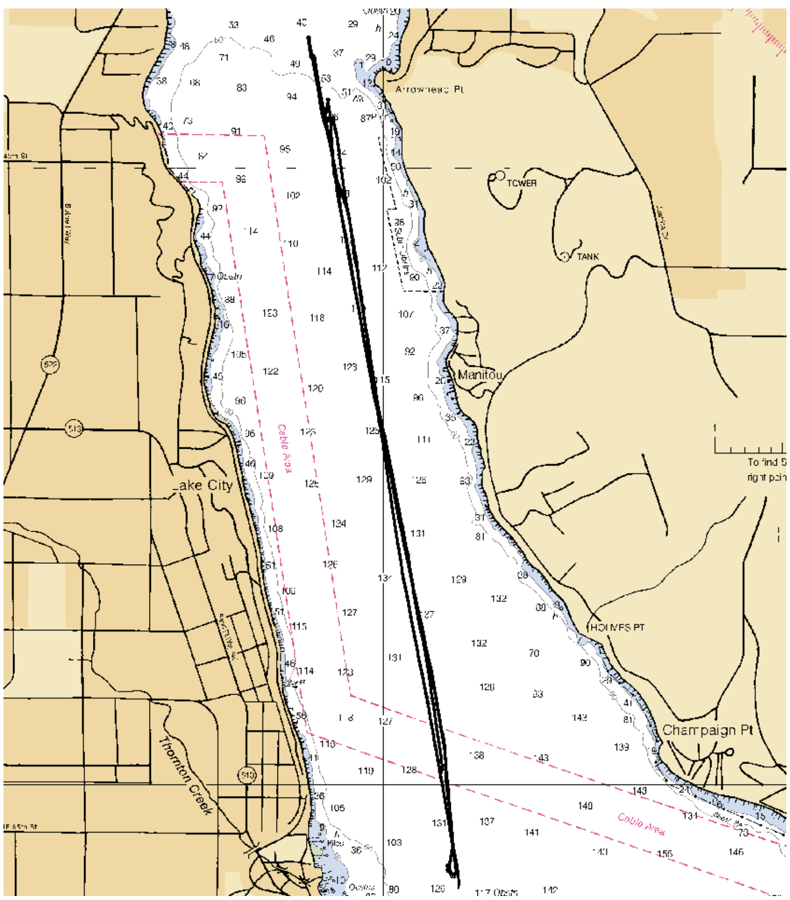



*Figure 1: Location of line for the Ellipsoid Reference Method, Chart 18447*

## Procedure for the Ellipsoidal Referenced Method:

The Ellipsoidally Referenced Dynamic Draft Measurement (ERDDM) methodology as outline in section 1.4.2.1.2.1 [Post-Processed Kinematic (PPK) GPS] of the Field Procedures Manual was used by *Rainier* to determine the settlement and squat values of her survey launches

For data acquisition, the launch was run on a constant heading line and speed was increased in two-knot increments from four to 10 knots at two-minute intervals during the line. A two minute rest period was placed between the runs. POSPac data recording began shortly after leaving the pier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by *Rainier*.

## Results and Final Error Estimates:

SST Gendron compiled the results from the data following the acquisition of the POS data. The POSPac data recorded by the POS MV was imported into the POSPac MMS software suite and processed using Single Baseline - Short Baseline processing. The data from the CORS station SEAI was selected as the reference station.

The resulting SBET was exported as an ASCII file, which was processed using the Pydro macro ProcSBETDynamicDraft.py. The resulting dynamic draft curve and table is shown below. Values generated using this method were compared to historic values and correlated well, with the ERDDM giving a more complete dynamic draft curve.

$+0.00177*X^4 -0.0273*X^3 +0.121*X^2 -0.148*X$

| Speed [m/s] | Delta Draft [m] |
|---|---|
| 0.00 | 0.00 |
| 0.50 | -0.05 |
| 1.00 | -0.05 |
| 1.50 | -0.03 |
| 2.00 | -0.00 |
| 2.50 | 0.03 |
| 3.00 | 0.05 |
| 3.50 | 0.06 |
| 4.00 | 0.05 |
| 4.50 | 0.03 |
| 5.00 | -0.02 |
| 5.50 | -0.07 |
| 6.00 | -0.13 |
| 6.50 | -0.18 |
| 7.00 | -0.21 |
| 7.50 | -0.21 |
| 8.00 | -0.16 |

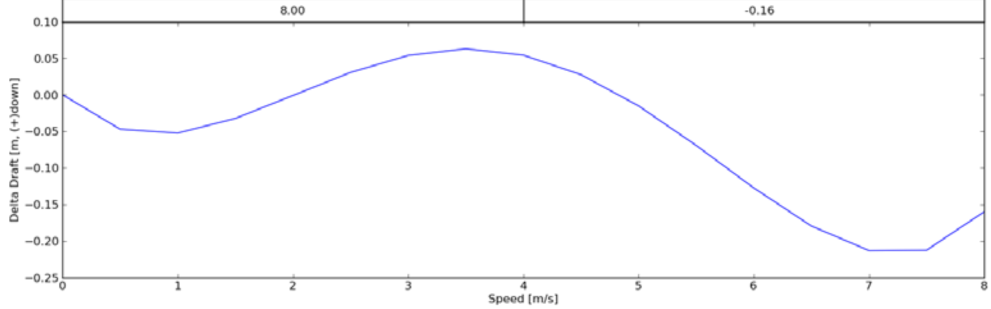


*Figure 2: Dynamic Draft Curve and Values Table Generated using the ERDDM Method*

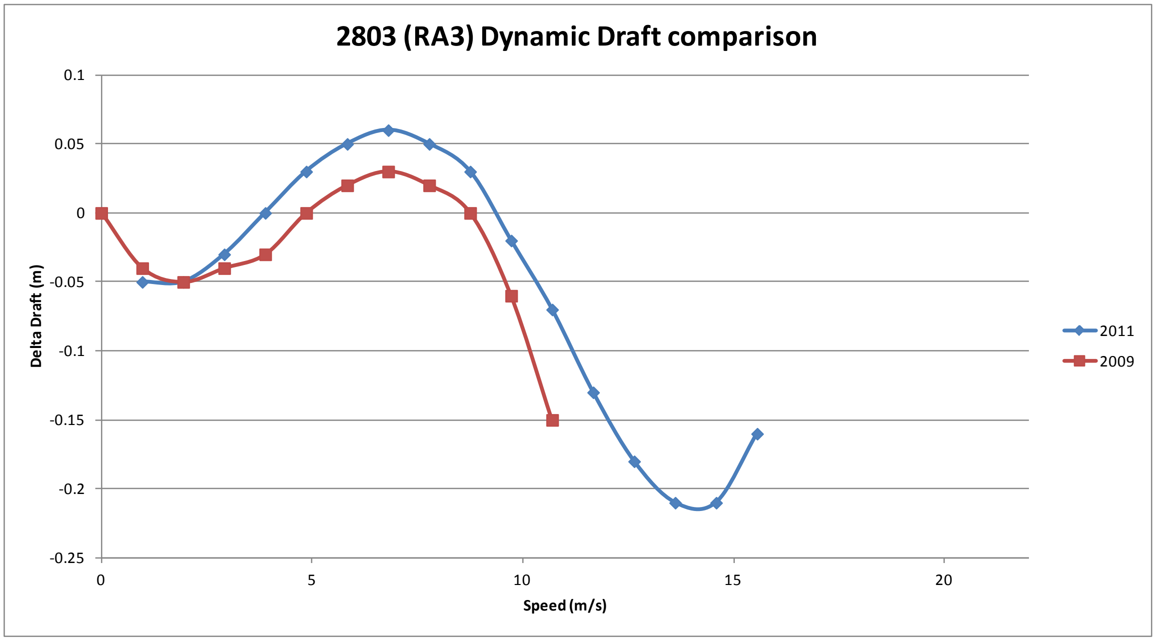



*Figure 3: Dynamic Draft Curve Comparison*

## Recommendations

It is the recommendation that the values generated using the ERDDM processing procedure in POSPac be used as the Dynamic Draft calibration for Vessel 2803. The data should be accepted, and the values calculated supersede prior values for the upcoming hydrographic season of 2011.

# 2804 Dynamic Draft
# SYSTEM READINESS REPORT 2011

**Vessel:** RA-6; Hull # 2804
**Sonar:** Reson 7125
**Written By:** CST Jacobson
**Report Date:** 5/13/2011

## Background:
Dynamic draft is the vertical displacement due to the combined effects of settlement and squat. The Field Procedures Manual requires settlement and squat to be measured at least once annually for each vessel.

## Calibration Location, Date, and Personnel:
The dynamic draft determination was performed in Lake Washington, WA.

**Personnel**: SST Gendron, AST Walsh, ENS Clark
**Coxwain**: SS Allen
**Location**: Lake Washington, WA
**Date**: 5/11/2011; DN 131

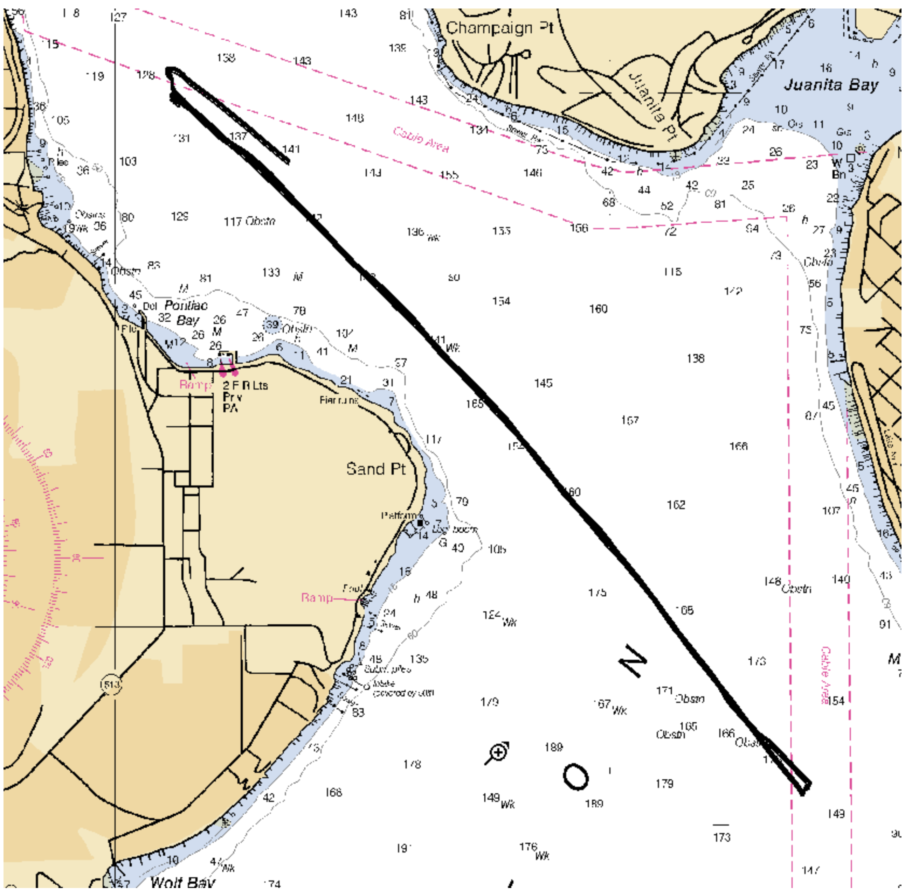



*Figure 1: Location of line for the Ellipsoid Reference Method, Chart 18447*

## Procedure for the Ellipsoidal Referenced Method:

The Ellipsoidally Referenced Dynamic Draft Measurement (ERDDM) methodology as outline in section 1.4.2.1.2.1 [Post-Processed Kinematic (PPK) GPS] of the Field Procedures Manual was used by *Rainier* to determine the settlement and squat values of her survey launches

For data acquisition, the launch was run on a constant heading line and speed was increased in two-knot increments from four to 10 knots at two-minute intervals during the line. A two minute rest period was placed between the runs. POSPac data recording began shortly after leaving the pier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by *Rainier*.

## Results and Final Error Estimates:

SST Gendron compiled the results from the data following the acquisition of the POS data. The POSPac data recorded by the POS MV was imported into the POSPac MMS software suite and processed using Smart Base processing. The data from the CORS stations SEAI, SEAT, PUPU, PFLD, and P426 were selected as the reference stations.

The resulting SBET was exported as an ASCII file, which was processed using the Pydro macro ProcSBETDynamicDraft.py. The resulting dynamic draft curve and table is shown below. Values generated using this method were compared to historic values and correlated well, with the ERDDM giving a more complete dynamic draft curve.

| | |
|---|---|
| 0.50 | -0.02 |
| 1.00 | -0.02 |
| 1.50 | -0.01 |
| 2.00 | 0.00 |
| 2.50 | 0.02 |
| 3.00 | 0.03 |
| 3.50 | 0.04 |
| 4.00 | 0.03 |
| 4.50 | 0.02 |
| 5.00 | -0.00 |
| 5.50 | -0.04 |
| 6.00 | -0.08 |
| 6.50 | -0.13 |
| 7.00 | -0.18 |
| 7.50 | -0.24 |
| 8.00 | -0.29 |
| 8.50 | -0.34 |
| 9.00 | -0.37 |
| 9.50 | -0.38 |
| 10.00 | -0.37 |
| 10.50 | -0.32 |
| 11.00 | -0.22 |

$+0.000522*X^4 -0.00966*X^3 +0.0463*X^2 -0.056*X$

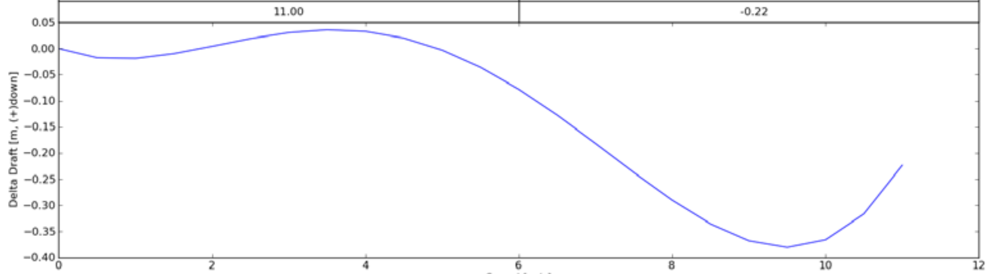



*Figure 2: Dynamic Draft Curve and Values Table Generated using the ERDDM Method*

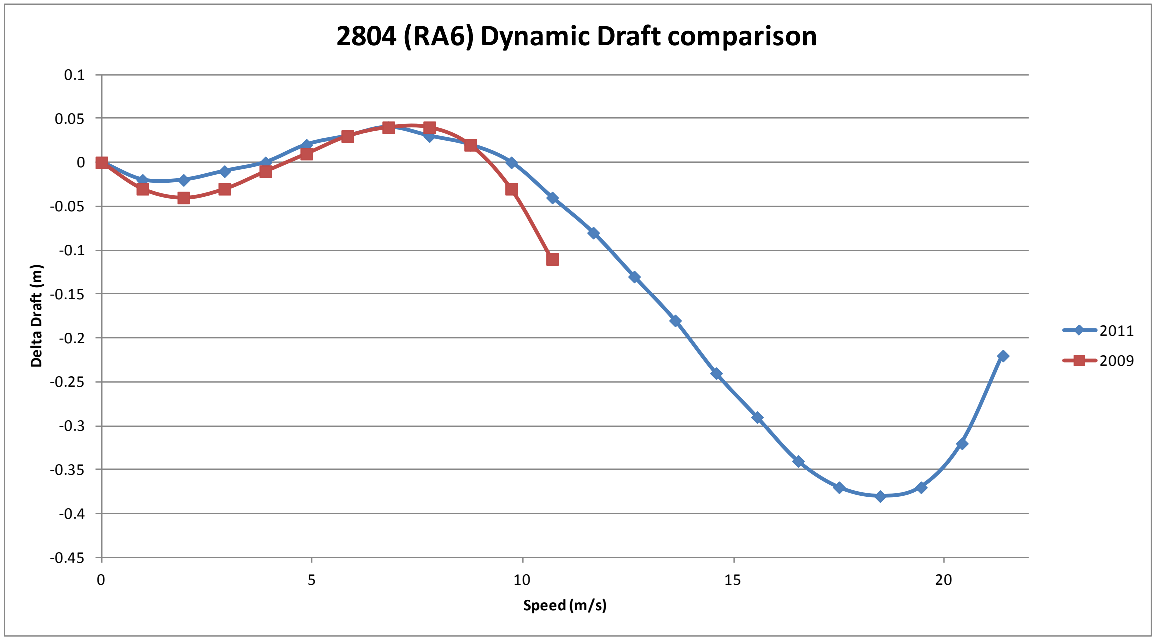



*Figure 3: Dynamic Draft Curve Comparison*

## Recommendations

It is the recommendation that the values generated using the ERDDM processing procedure in POSPac be used as the Dynamic Draft calibration for Vessel 2804. The data should be accepted, and the values calculated supersede prior values for the upcoming hydrographic season of 2011.

# S221 Dynamic Draft
# SYSTEM READINESS REPORT 2011

**Vessel:** *Rainier*; Hull # S221
**Sonar:** Simrad EM710
**Written By:** CST Jacobson
**Report Date:** 6/10/2011

## Background:
Dynamic draft is the vertical displacement due to the combined effects of settlement and squat. The Field Procedures Manual requires settlement and squat to be measured at least once annually for each vessel.

## Calibration Location, Date, and Personnel:
The dynamic draft determination was performed in Lake Washington, WA.

**Personnel**: *Rainier* survey department
**Coxwain**: Bridge Watch
**Location**: Lake Washington, WA
**Date**: 6/9/2011; DN 160

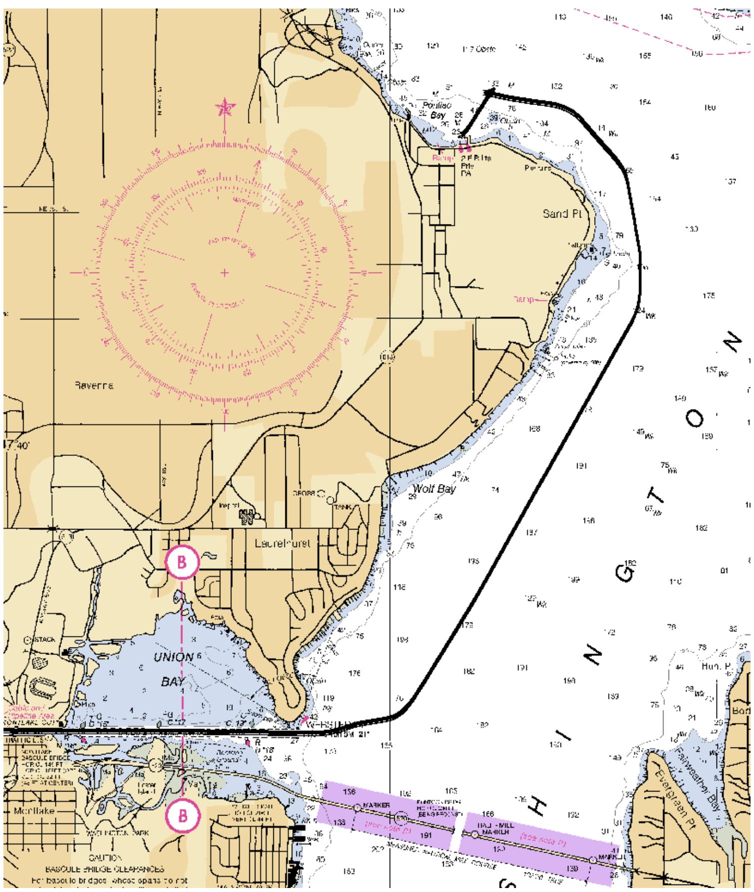



*Figure 1: Location of line for the Ellipsoid Reference Method, Chart 18447*

## Procedure for the Ellipsoidal Referenced Method:

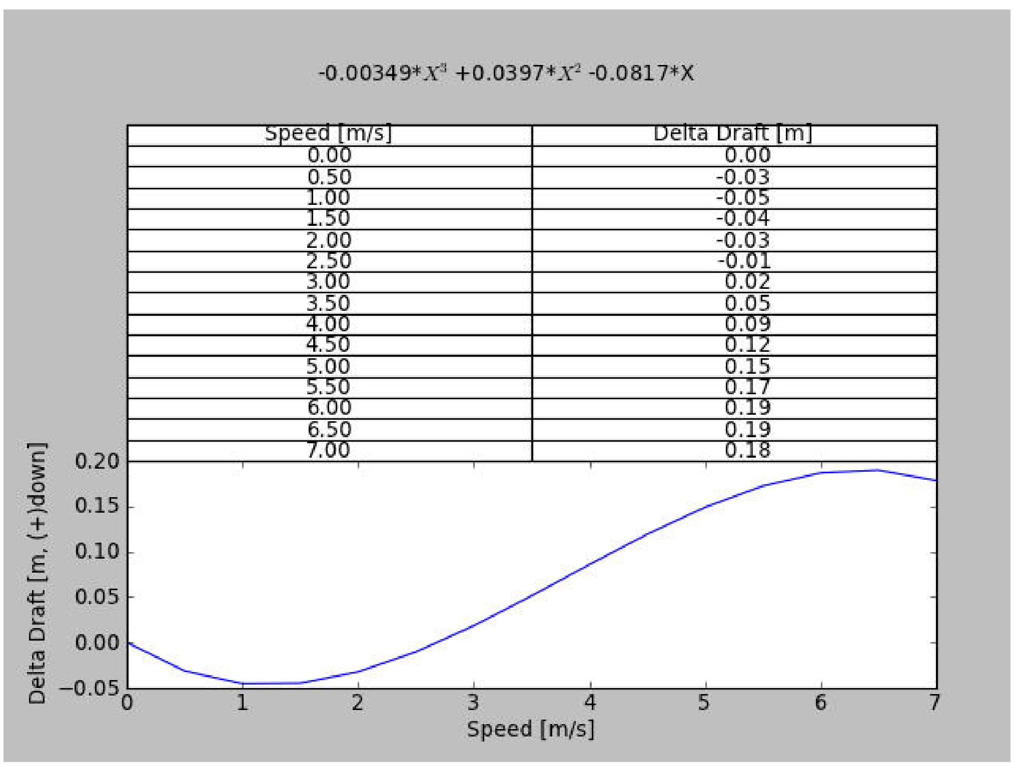
The Ellipsoidally Referenced Dynamic Draft Measurement (ERDDM) methodology as outline in section 1.4.2.1.2.1 [Post-Processed Kinematic (PPK) GPS] of the Field Procedures Manual was used by *Rainier* to determine the settlement and squat values of the ship.

For data acquisition, *Rainier* ran on a constant heading line and speed was increased in two-knot increments from four to 10 knots at two-minute intervals during the line. POSPac data recording began shortly after leaving the pier. Continuously Operating Reference Stations (CORS) were used as reference stations, no GPS base stations were installed by *Rainier*.

## Results and Final Error Estimates:

SST Gendron compiled the results from the data following the acquisition of the POS data. The POSPac data recorded by the POS MV was imported into the POSPac MMS software suite and processed using Smart Base processing. The data from the CORS stations SEAT, SEA1, PFLD, PUPU, RPT6, P437, P426, and KTBW were selected as the reference stations.

The resulting SBET was exported as an ASCII file, which was processed using the Pydro macro ProcSBETDynamicDraft.py. The resulting dynamic draft curve and table is shown below. Values generated using this method were compared to historic values and correlated well, with the ERDDM giving a more complete dynamic draft curve.




$-0.00349*X^3 +0.0397*X^2 -0.0817*X$

| Speed [m/s] | Delta Draft [m] |
|---|---|
| 0.00 | 0.00 |
| 0.50 | -0.03 |
| 1.00 | -0.05 |
| 1.50 | -0.04 |
| 2.00 | -0.03 |
| 2.50 | -0.01 |
| 3.00 | 0.02 |
| 3.50 | 0.05 |
| 4.00 | 0.09 |
| 4.50 | 0.12 |
| 5.00 | 0.15 |
| 5.50 | 0.17 |
| 6.00 | 0.19 |
| 6.50 | 0.19 |
| 7.00 | 0.18 |

*Figure 2: Dynamic Draft Curve and Values Table Generated using the ERDDM Method*

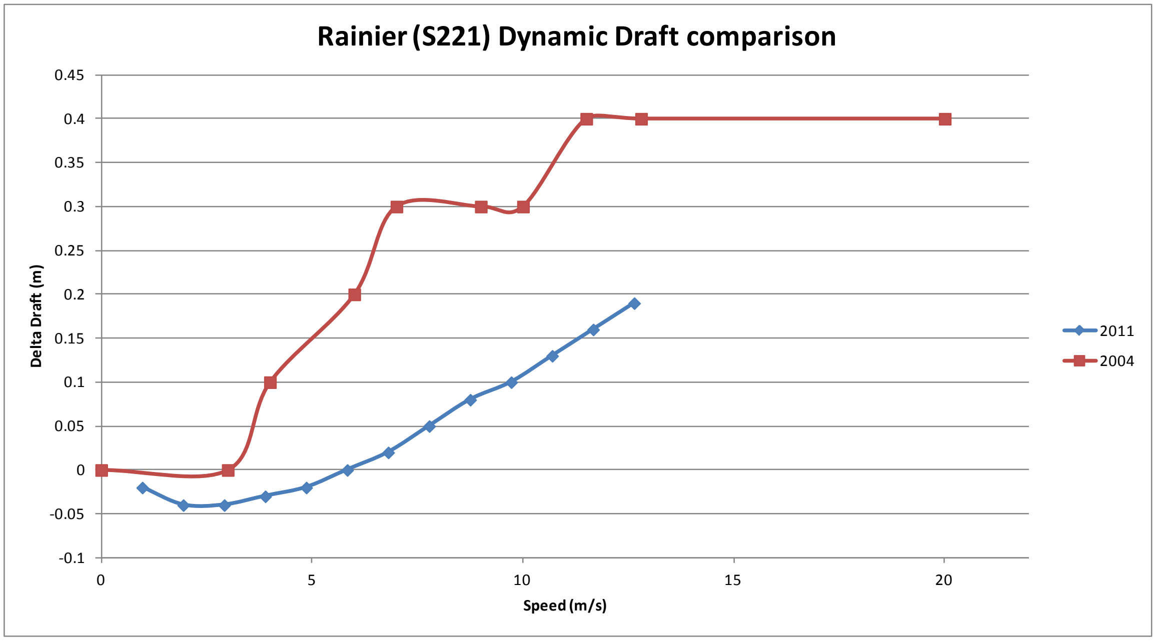



*Figure 3: Dynamic Draft Curve Comparison*

## Recommendations

It is the recommendation that the values generated using the ERDDM processing procedure in POSPac be used as the Dynamic Draft calibration for *Rainier* (S221). The data should be accepted, and the values calculated supersede prior values for the upcoming hydrographic season of 2011.

# Patch Tests

# RAINIER SURVEY LAUNCH 4 (2801) HF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2801 (RA-4)
**Sonar**: Reson 7125, 400 kHz, 512 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 4707073
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

## Background:

Launch 2801 (RA-4) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:

The calibration for 2801 (RA-4) was completed on May 26, 2011 (DN146). Reson 7125 400 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: BGL Anderson, LTJG Andvick, ENS Clark, AST Bowker
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 26, 2011 (DN146)

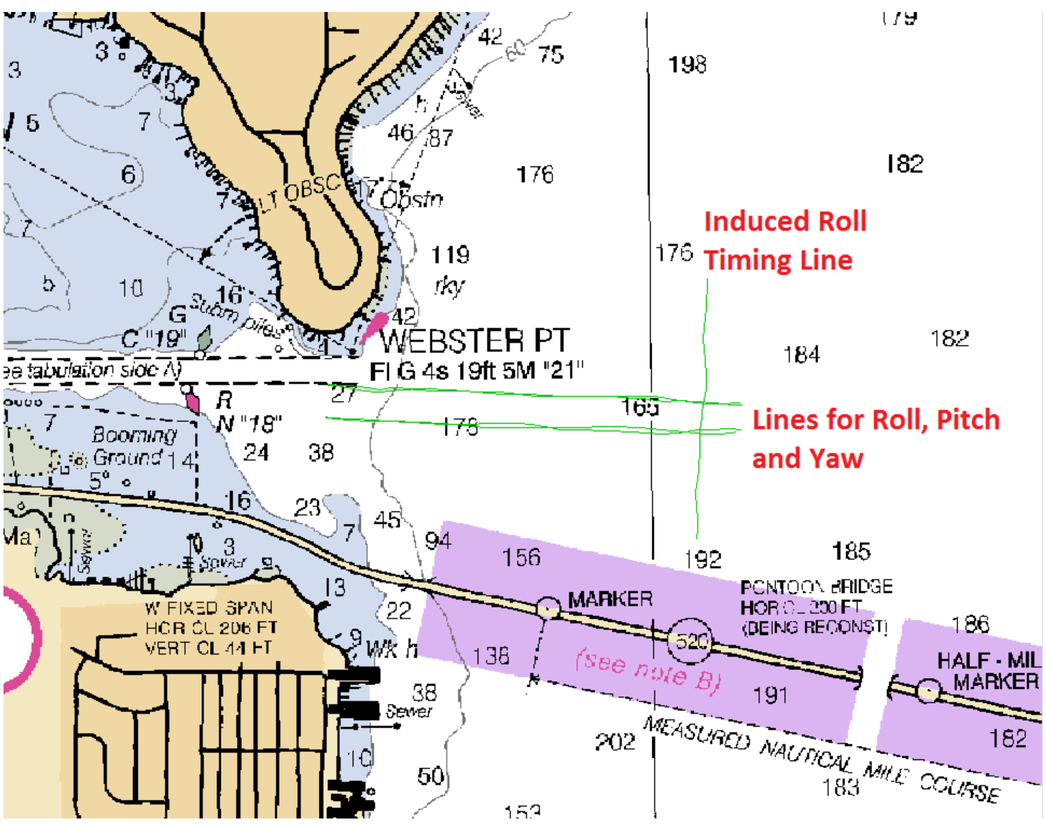



**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2801. Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_2110 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001_2203 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_2139 | S | 4 kts | Timing | Induced Roll |
| 003_2147 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_2155 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST Todd Walsh, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2801 (RA-4). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | 0.000 |
| Pitch | -1.000 | 0.327 |
| Roll | -0.231 | 0.007 |
| Yaw | 0.531 | 0.076 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2801 were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2801's 400 kHz HVF.

# RAINIER SURVEY LAUNCH 4 (2801) LF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2801 (RA-4)
**Sonar**: Reson 7125, 200 kHz, 256 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 4707073
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

**Background:**
Launch 2801 (RA-4) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about 1/2 of the way aft of the bow.

**Calibration Location, Date, and Personnel:**
The calibration for 2801 (RA-4) was completed on May 31, 2011. Reson 7125 200 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: BGL Anderson, LTJG Andvick, ENS Manda, AST Doroba
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 31, 2011 (DN151)

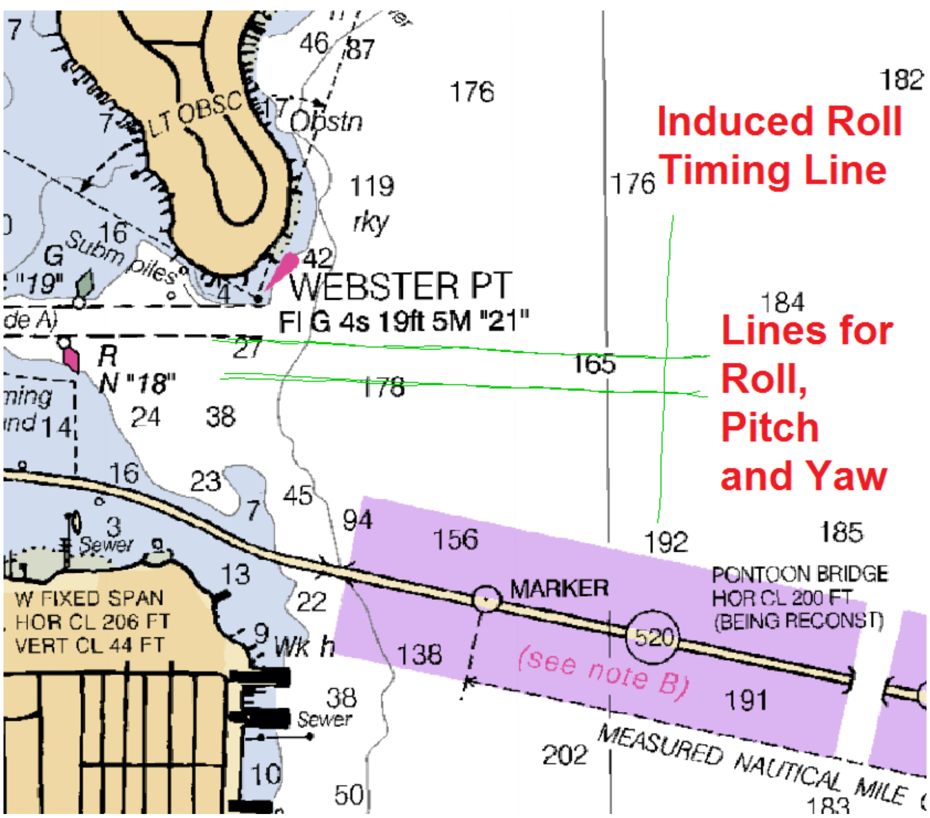



**Figure 1. Patch test lines for calibration of Reson 7125, near Sand Point, WA (Chart 18447).**

## Data Acquisition Procedure:
The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2801. Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_1623 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001_1631 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_1549 | S | 4 kts | Timing | Induced Roll |
| 003_1640 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_1648 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:
Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:
The following table shows the biases that were calculated for the Reson 7125 on 2801 (RA-4). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | 0.00 |
| Pitch | -1.340 | 0.00 |
| Roll | -0.250 | 0.00 |
| Yaw | 1.070 | 0.00 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2801 were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2801's 200 kHz HVF.

# RAINIER SURVEY LAUNCH 5 (2802) HF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2802 (RA-5)
**Sonar**: Reson 7125, 400 kHz, 512 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 4407018
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

## Background:

Launch 2802 (RA-5) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:

The calibration for 2802 (RA-5) was completed on May 25, 2011 (DN145). Reson 7125 400 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: BGL Anderson, SST Gendron, ENS Clark, AST Doroba
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 25, 2011 (DN145)

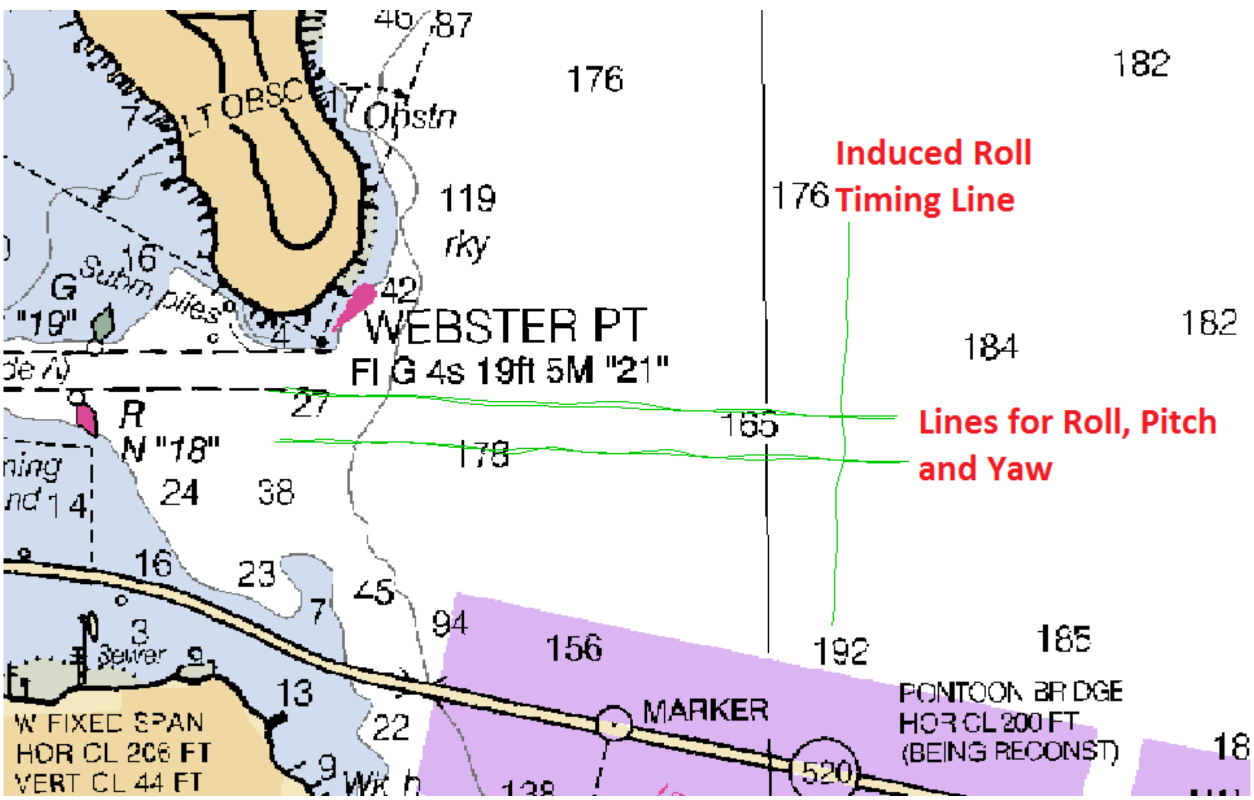



**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2802 (RA-5). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_2152 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001_2159 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_2145 | S | 4 kts | Timing | Induced Roll |
| 003_2206 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_2214 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2802 (RA-5). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | 0.000 |
| Pitch | -1.069 | 0.293 |
| Roll | -0.204 | 0.011 |
| Yaw | 0.540 | 0.290 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2802 (RA-5) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2802's 400 kHz HVF.

# RAINIER SURVEY LAUNCH 5 (2802) LF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2802 (RA-5)
**Sonar**: Reson 7125, 200 kHz, 256 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 4407018
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

## Background:

Launch 2802 (RA-5) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:

The calibration for 2802 (RA-5) was completed on May 25, 2011 (DN145). Reson 7125 200 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: BGL Anderson, SST Gendron, ENS Clark, AST Doroba
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 25, 2011 (DN145)

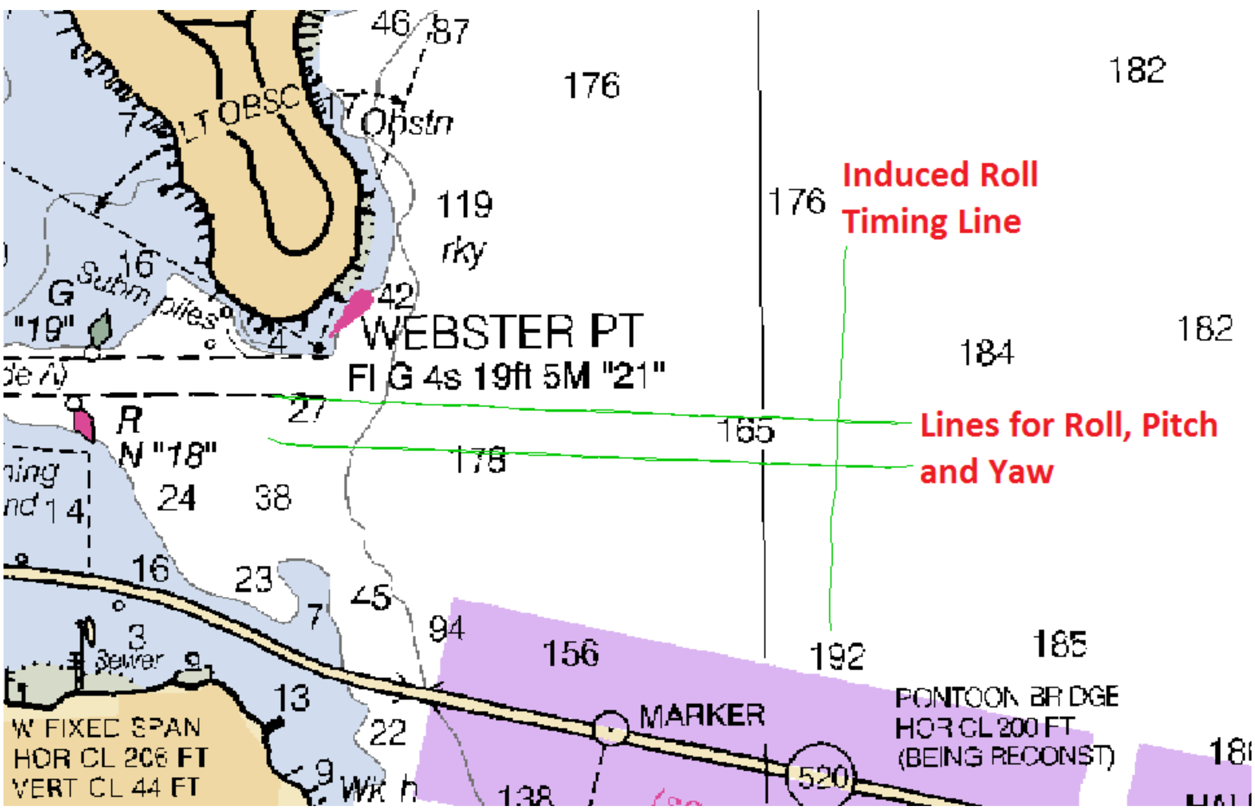



**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2802 (RA-5). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_2105 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001-2113 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_2057 | S | 4 kts | Timing | Induced Roll |
| 003_2124 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_2132 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST Todd Walsh, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2802 (RA-5). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| **Attribute** | **Value** | **Standard Deviation** |
|---|---|---|
| Timing | 0 | 0.000 |
| Pitch | -0.982 | 0.341 |
| Roll | -0.204 | 0.005 |
| Roll | 0.310 | 0.146 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2802 (RA-5) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2802's 200 kHz HVF.

## RAINIER SURVEY LAUNCH 3 (2803) HF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2803 (RA-3)
**Sonar**: Reson 7125, 400 kHz, 512 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 2708010
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

### Background:
Launch 2803 (RA-3) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

### Calibration Location, Date, and Personnel:
The calibration for 2803 (RA-3) was completed on May 31, 2011 (DN151). Reson 7125 400 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: SS Allen, SST Gendron, ENS Prole, ENS Phillips
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 31, 2011 (DN151)

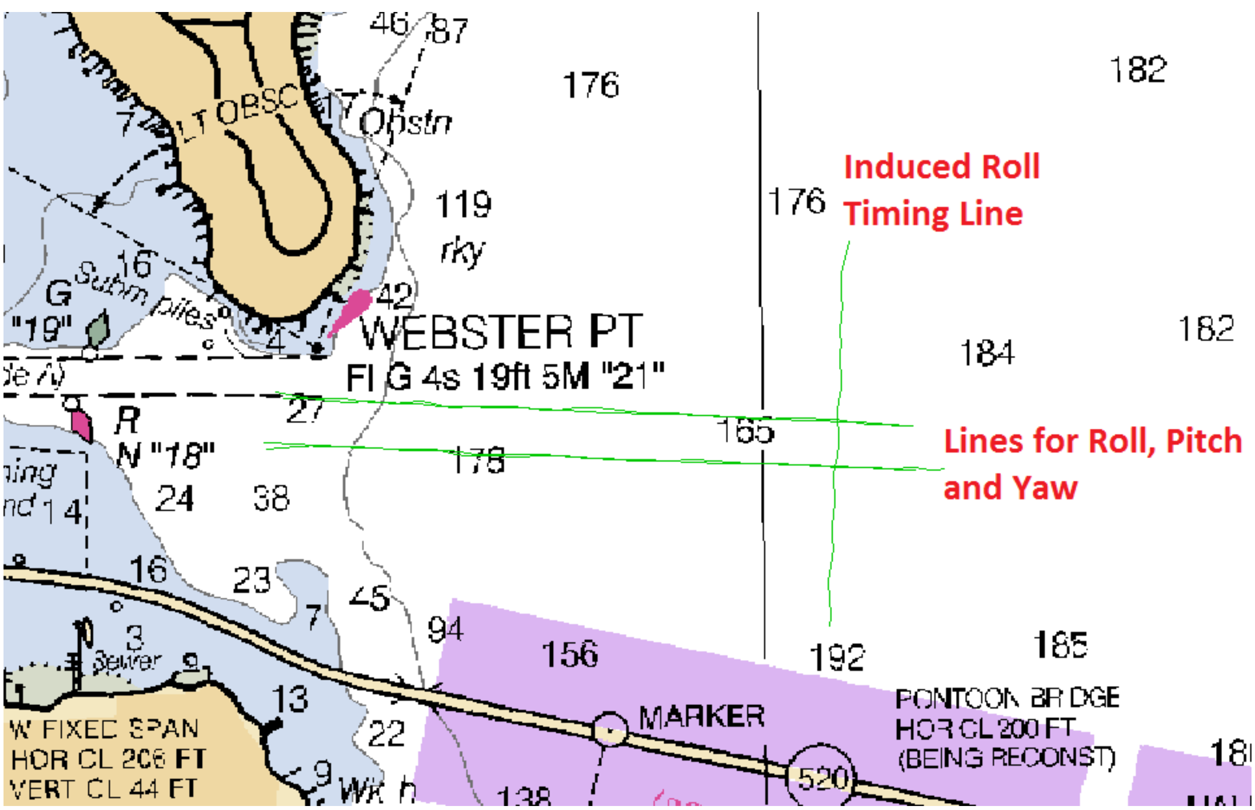



**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2803 (RA-3). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_2121 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001_2129 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_2115 | S | 4 kts | Timing | Induced Roll |
| 003_2137 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_2145 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2803 (RA-3). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | 0.000 |
| Pitch | -0.260 | 0.065 |
| Roll | -0.096 | 0.008 |
| Yaw | 0.399 | 0.122 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2803 (RA-3) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2803's 400 kHz HVF.

# RAINIER SURVEY LAUNCH 3 (2803) LF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2803 (RA-3)
**Sonar**: Reson 7125, 200 kHz, 256 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 2708010
**Date of Current Vessel Offset Measurement/Verification**: April 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 9, 2011

## Background:

Launch 2803 (RA-3) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:

The calibration for 2803 (RA-3) was completed on May 31, 2011 (DN151). Reson 7125 200 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: SS Allen, SST Gendron, ENS Prole, ENS Phillips
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 31, 2011 (DN151)

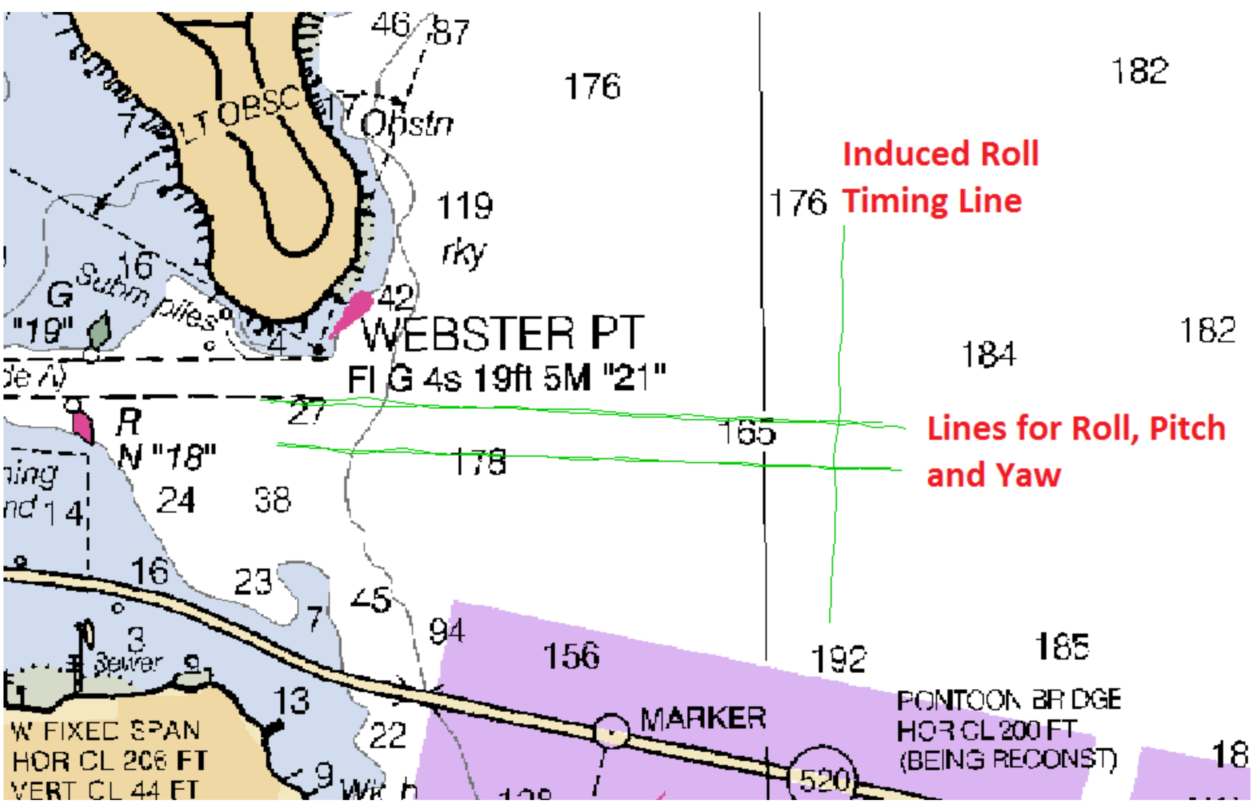



**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2803 (RA-3). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_2037 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001-2044 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_22030 | S | 4 kts | Timing | Induced Roll |
| 003_2053 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_2101 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2803 (RA-3). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| **Attribute** | **Value** | **Standard Deviation** |
|---|---|---|
| Timing | 0 | 0.00 |
| Pitch | -0.417 | 0.086 |
| Roll | -0.106 | 0.006 |
| Yaw | 0.651 | 0.018 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2803 (RA-3) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2803's 200 kHz HVF.

# RAINIER SURVEY LAUNCH 3 (2803) RESON 8125 PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2803 (RA-3)
**Sonar**: Reson 8125 455 kHz multibeam
**Sonar Mounting Configuration**: hull mounted, tilted 34 degrees starboard
**Processor Serial Number**: 29979
**Date of Current Vessel Offset Measurement/Verification**: September 19, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** March 22, 2012

## Background:

Launch 2803 (RA-3) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a 34 degree starboard tilted Reson 8125, a multibeam sonar system with a flat-faced transducer, which is attached with a custom made aluminum bracket bolted to the forward hull hardpoint on the starboard side. The transducer is mounted on a 34 degree tilt to starboard in order to facilitate inshore acquisition in near shore areas.

## Calibration Location, Date, and Personnel:

The calibration for 2803 (RA-3) was completed on May 31, 2011 (DN151). Reson 8125 system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: SS Foye, LT Gonsalves, HAST Geiger
**Location**: Vicinity of Pigeon Island, Paloma Pass, Alaska.
**Weather:** cloudy, rain
**Date**: October 3, 2011 (DN276)

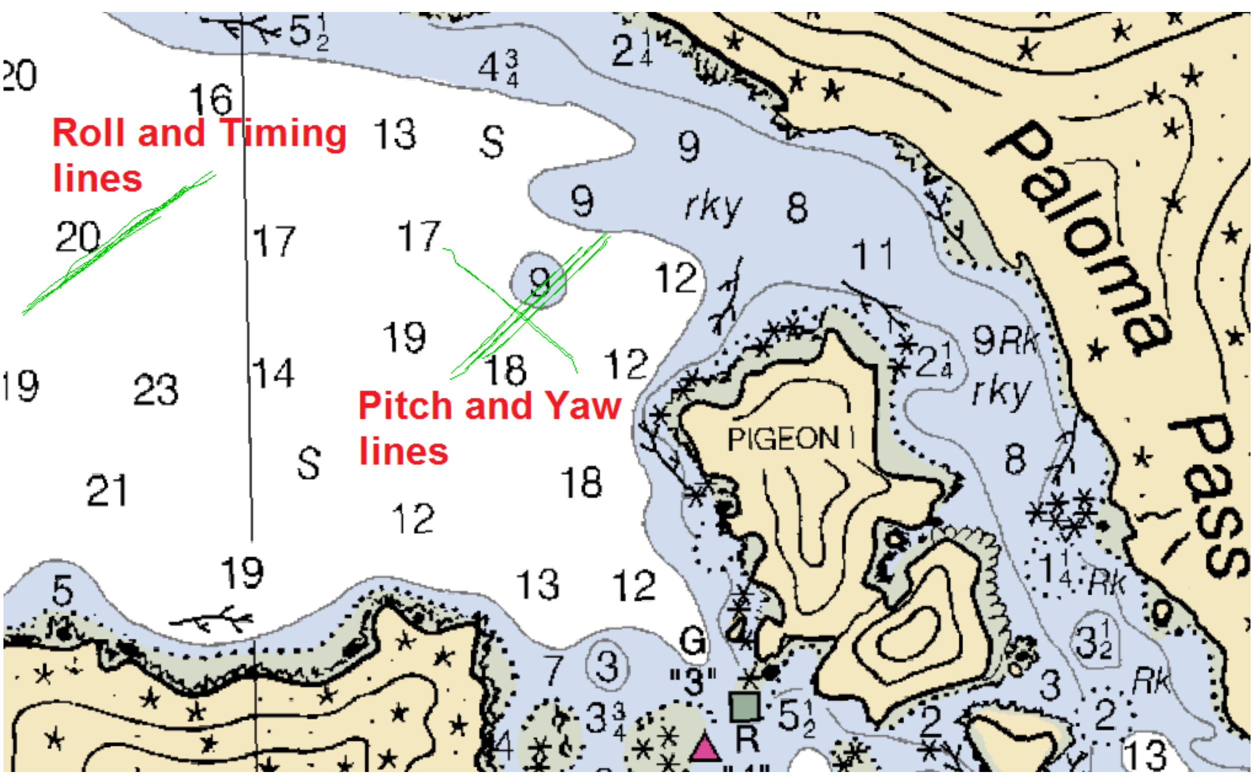



**Figure 1. Patch test lines for calibration of Reson 8125, near Pigeon Islans, AK (Chart 17406).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2803 (RA-3). Timing bias was determined using the induced roll method, pitch bias and yaw bias using a target, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 1905 | S | 6.5 kt | timing | Induced roll |
| 1908 | N | 6.5 kt | timing | Induced roll |
| 1911 | S | 6 kt | roll | flat bottom |
| 1914 | N | 6 kt | roll | flat bottom |
| 1918 | S | 7.5 kt | roll | flat bottom |
| 1921 | N | 7.5 kt | roll | flat bottom |
| 1926 | N | 6 kt | yaw | target |
| 1929 | S | 6 kt | yaw | target |
| 1933 | N | 7.5 kt | yaw | target |
| 1935 | S | 7.5 kt | yaw | target |
| 1938 | N | 7.5 kt | Pitch | target |
| 1941 | S | 7.5 kt | Pitch | target |
| 1943 | N | 6 kt | Pitch | target |
| 1946 | S | 6 kt | Pitch | target |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 8125 on 2803 (RA-3). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | -2.16 | 0.010 |
| Pitch | 0.792 | 0.305 |
| Roll | -0.092 | 0.194 |
| Yaw | -1.992 | 0.232 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2803 (RA-3) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2803's 8125 HVF.

**RAINIER SURVEY LAUNCH 6 (2804) HF RESON PATCH TEST**
**SYSTEM READINESS REPORT 2011**

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**Vessel**: 2804 (RA-6)
**Sonar**: Reson 7125, 400 kHz, 512 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 2708007
**Date of Current Vessel Offset Measurement/Verification**: May 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 28, 2011

## Background:
Launch 2804 (RA-6) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:
The calibration for 2804 (RA-6) was completed on May 24, 2011 (DN144). Reson 7125 400 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: SS Anderson, SST Gendron, AST Cruz, AT Geiger
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 24, 2011 (DN144)

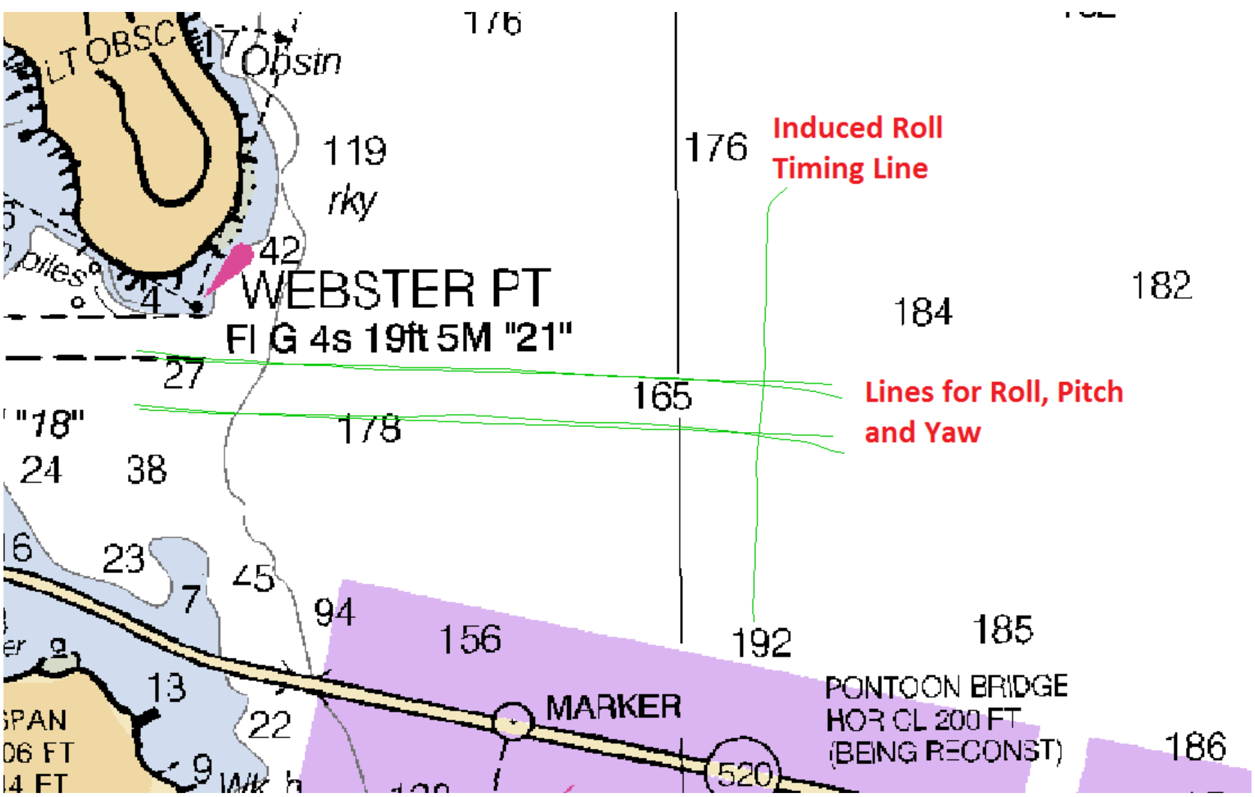


**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2803 (RA-3). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_1736 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001_17445 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_1729 | S | 4 kts | Timing | Induced Roll |
| 003_1752 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_1800 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, AST John Doroba, SST Jennifer Wilson, PS Toshi Wozumi and LT Olivia Hauser. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2804 (RA-6). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0.000 | 0.000 |
| Pitch | -0.731 | 0.342 |
| Roll | 0.727 | 0.012 |
| Yaw | -0.628 | 0.855 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2804 (RA-6) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2804's 400 kHz HVF.

# RAINIER SURVEY LAUNCH 6 (2804) LF RESON PATCH TEST SYSTEM READINESS REPORT 2011

**Vessel**: 2804 (RA-6)
**Sonar**: Reson 7125, 200 kHz, 256 beams
**Sonar Mounting Configuration**: hull mounted
**Processor Serial Number**: 2708007
**Date of Current Vessel Offset Measurement/Verification**: May 12, 2011
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: Seacat SBE19+ sound velocity profiler
**Written By:** HCST James Jacobson
**Report Date:** June 28, 2011

## Background:

Launch 2804 (RA-6) is a 29 ft Diesel Aluminum boat capable of acquiring multibeam bathymetry. It is equipped with a Reson 7125, a multibeam sonar system with a flat-faced transducer, which is mounted on the centerline of the vessels keel about ½ of the way aft of the bow.

## Calibration Location, Date, and Personnel:

The calibration for 2804 (RA-6) was completed on May 24, 2011 (DN144). Reson 7125 400 kHz system setup and data collection were performed in accordance with NOS specifications.
**Launch Personnel**: SS Anderson, SST Gendron, AST Cruz, AT Geiger
**Location**: Vicinity of Webster Point, Lake Washington, Washington
**Weather:** Partly cloudy, calm
**Date**: May 24, 2011 (DN144)

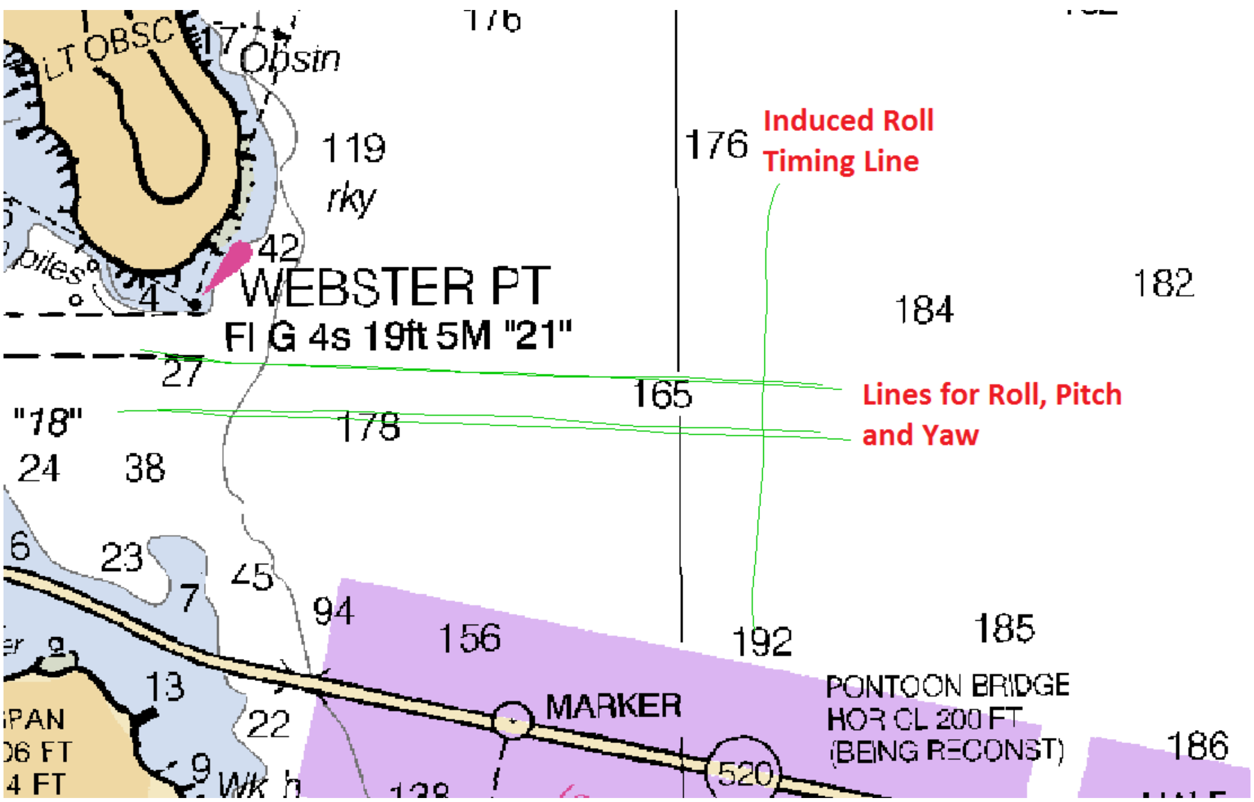


**Figure 1. Patch test lines for calibration of Reson 7125, near Webster Point, WA (Chart 18447).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for launch 2804 (RA-6). Timing bias was determined using the induced roll method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 001_1649 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 001-1657 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 002_1641 | S | 4 kts | Timing | Induced Roll |
| 003_1706 | W | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 003_1714 | E | 4 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, SST Jennifer Wilson, LT Olivia Hauser, AST John Doroba, and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

## Results and Final Error Estimates:

The following table shows the biases that were calculated for the Reson 7125 on 2804 (RA-6). The following table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| **Attribute** | **Value** | **Standard Deviation** |
|---|---|---|
| Timing | 0 | 0.00 |
| Pitch | 0.622 | 0.063 |
| Roll | 0.815 | 0.017 |
| Yaw | -0.179 | 0.078 |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for vessel 2804 (RA-6) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel 2804's 200 kHz HVF.

# RAINIER S221 Simrad-EM710 PATCH TEST
# SYSTEM READINESS REPORT 2011

**Vessel**: S221 (RAINIER)
**Sonar**: Simrad-EM710, 70 to 100 kHz, 256 beams
**Sonar Mounting Configuration**: hull mounted
**Sonar Serial Number**: 218
**Date of Current Vessel Offset Measurement/Verification**: October 12, 2010
**Position/Attitude Sensor**: TSS POS/MV 320 (version 4)
**SVP**: ODIM MVP200 moving vessel profiler
**Written By:** HCST James Jacobson
**Report Date:** July 12, 2011

**Background:**
S221 (RAINIER) a 231 ft class II hydrographic ship equipped with a Simrad-EM710 multibeam echosounder. The EM710 operates at sonar frequencies in the 70 to 100 kHz range, with a maximum range up to 2000 meters. The system utilizes composite transducer arrays in a Mills cross configuration with a ½° by 1° beamwidth option mounted to the hull of the vessel. The transmit fan is electronically stabilized for roll, pitch and yaw.

**Calibration Location and Date:**
The calibration for S221 (RAINIER) was completed on June 8, 2011. Simrad-EM710 system setup and data collection were performed in accordance with NOS specifications.
**Location**: Port Madison, Puget Sound, Washington
**Weather:** Partly cloudy, calm
**Date**: June 8, 2011 (DN158)

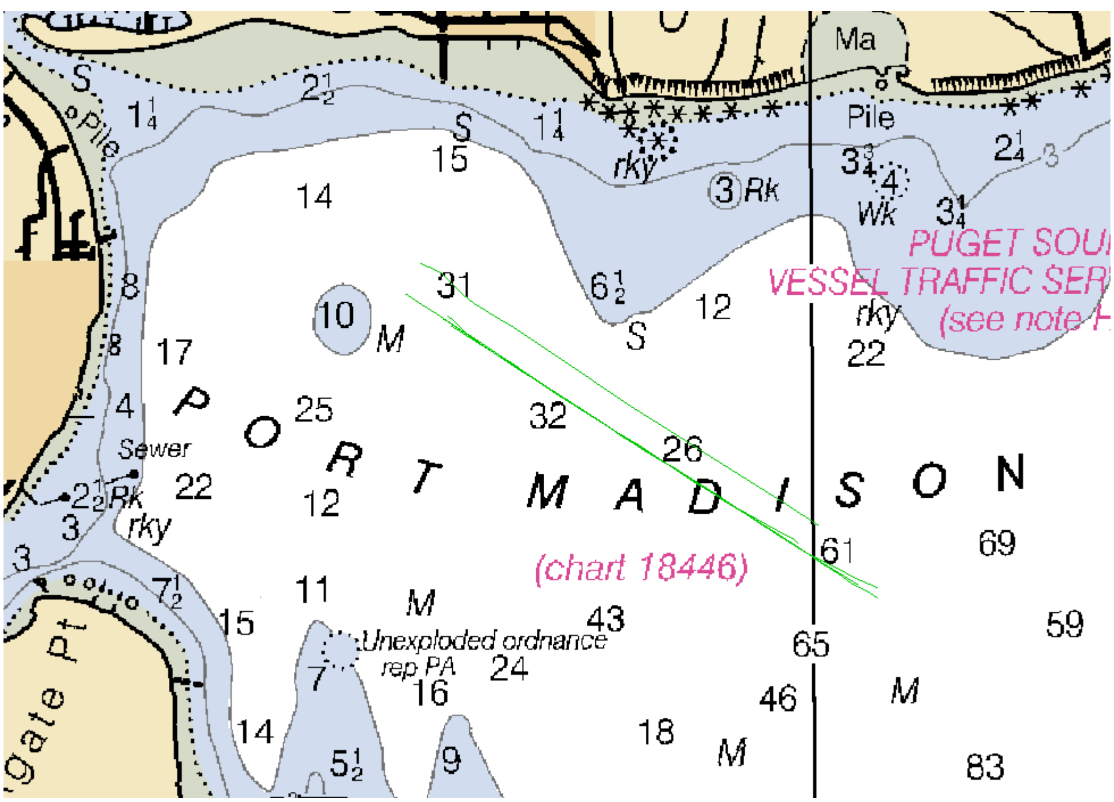


**Figure 1. Patch test lines for calibration of Simrad-EM710, Port Madison, WA (Chart 18441).**

## Data Acquisition Procedure:

The following evaluation procedures, as described in the Field Procedures Manual dated May 2011, were utilized to analyze the patch test data acquired for S221 (RAINIER). Timing bias was determined using the slope comparison method, pitch bias and yaw bias using slope method, and roll bias using the standard flat bottom method.

| Line | Direction | Speed | Reason | Method |
|---|---|---|---|---|
| 0002_20110608_015159 | NW | 2 kts | Pitch/Roll | Slope/Flat bottom |
| 0003_20110608_022030 | SE | 2 kts | Pitch/Roll/Yaw | Slope/Flat bottom/Slope |
| 0004_20110608_024504 | NW | 4 kts | Timing | Slope |
| 0005_20110608_030125 | SE | 2 kts | Yaw | Slope |
| 0006_20110608_032608 | NW | 2 kts | Pitch/Roll | Slope/Flat bottom |

## Data Processing Procedure:

Data was converted in CARIS HIPS version 7.1 using an HVF file with heave, pitch, roll and timing values set to zero. True heave, water levels and sound velocity were applied and the data merged before cleaning via swath editor. Biases were determined using Caris HIPS 7.1 Calibration tool by the following hydrographers: CST Jim Jacobson, LT Olivia Hauser and PS Toshi Wozumi. Bias values determined by each individual were examined by the reviewer, and obvious outliers rejected. The accepted values were averaged to establish the final correctors to be added to the CARIS HVF.

### Results and Preliminary Error Estimates:

The following table shows the biases that were calculated for the Simrad-EM710 on S221 (RAINIER). This table includes the calculated values and the standard deviation of the values calculated for 2011. Each 2011 data point is an average of five data points, calculated by the individual hydrographers.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | 0.000 |
| Pitch | 0.540 | 0.290 |
| Roll | 0.172 | 0.000 |
| Yaw | 0.812 | 0.887 |

### Final Error Estimates:

As part of the procurement package for the EM710, personnel from Kongsberg were aboard *Rainier* from June 20 to June 24, 2011 for a Sea Acceptance Test (SAT). At the beginning of this test Kongsberg personnel, utilizing their own software obtained roll, pitch and heading biases and navigation timing errors. With the exception of pitch, these values were in general agreement with the values obtained by Rainier. The decision was made to use the values produced by Kongsberg as shown in the table below, for the final HVF values.

| Attribute | Value | Standard Deviation |
|---|---|---|
| Timing | 0 | n/a |
| Pitch | -0.70 | n/a |
| Roll | 0.14 | n/a |
| Yaw | 0.73 | n/a |

## Final HVF Recommendations:

2011 biases were reviewed by LT Olivia Hauser and CST Jim Jacobson. The average values calculated for S221 (RAINIER) were applied to the HVF when processing the reference surface lines. RAINIER recommends the calculated values for 2011 be the final biases included in vessel S221's Simrad EM710 HVF.