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NATIONAL OCEAN SERVICE

Data Acquisition and Processing Report

Type of Survey Hydrographic

Project No. S-N922-RA-08

Time Frame September 2008

LOCALITY

State Washington

General Locality Grays Harbor

2008

CHIEF OF PARTY
Captain Donald W. Haines, NOAA

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Data Acquisition and Processing Report
NOAA Ship *Raiuier* (s221)

S-N922-RA-08
Approaches to Grays Harbor, Washington
Hydrographic Survey Project Instructions dated July 17, 2008
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. Data were acquired by the following *Rainier* survey launches:

Hull Number	Vessel type
1101	29 foot Jensen jet drive survey launch
1021	29 foot Jensen survey launch
2801	28 foot Jensen survey launch
2802	28 foot Jensen survey launch
1015	29 foot Jensen survey launch

Vessels 1101, 1021, 2801, 2802 and 1015 were used to acquire shallow-water multibeam (SWMB) data and sound velocity profiles. Vessel 2802 was also used to collect side-scan-sonar (SSS) data. No unusual vessel configurations or problems were encountered on this project. Vessel descriptions and offset measurements are included in the *2008 NOAA Ship Rainier Hydrographic Readiness Review Package*.

Four different categories of echosounder systems were utilized for project S-N922-RA-08. 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 *2008 NOAA Ship Rainier Hydrographic Readiness Review Package.*

Sounding Equipment:

1. RESON 8101 Launch Shallow Water Multibeam (SWMB)

Vessels 1021 and 1015 were equipped with Reson SeaBat 8101 multibeam echosounders. The SeaBat 8101 is a 240 kHz multibeam system that measures relative water depths across a 150^o swath, consisting of 101 individual 1.5^o x 1.5^o beams. This system was used to obtain full-bottom coverage in depths generally from 4 meters to 150 meters, with varying range scale values dependent upon the depth of water and across-track slope. This system has an Option 033, Angle-Independent Imagery, and Option 040, Extended Range Projector.

Vessel 1021 is configured with the Reson 8101 mounted on a swing-arm which deploys the transducer from an “in transit” position recessed within the hull to a “survey” position extending beneath the hull before data acquisition commences.

Vessel 1015 is configured with the 8101 transducer rigidly attached to the hull mounted sled. This sled is designed for the relatively easy interchanging of various SWMB and SSS systems.

Figure 1 Reson 8101 sonar head, as installed on Launch 1015 (RA-6)

2. RESON 8125 Launch Shallow Water Multibeam (SWMB)

Vessel 1101 is equipped with a hull-mounted Reson SeaBat 8125, with Option 033, Angle-Independent Imagery. The SeaBat 8125 is a 455 kHz multibeam system that uses high frequency focused near-field beam forming to measure relative water depths across a 120° swath, consisting 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 Odom Digibar Pro, model db1200, velocimeter and digitally input into the Seabat 8125 during acquisition.

For the 2008 field season the SeaBat 8125 was mounted with a 30° angle looking towards starboard. In this configuration, 1101 could be run along the 30-foot contour parallel to shore during periods of high tide and produce near 100% SWMB coverage between the 8 and 4 meter depth curves. Under certain conditions depths up to the 0-meter curve were obtained.

3. RESON 7125 Launch Shallow Water Multibeam (SWMB)

Vessels 2801 and 2802 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 collect 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 ½° x 1°. At 200kHz, the SeaBat 7125 generates 128 or 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.

Side Scan Sonar:

1. Klein 5500

The Klein 5500 sonar system consists of a towfish, a transceiver/processor unit, and a PC for system control, data logging, and data viewing. The Klein 5500 simultaneously forms multiple dynamically focused beams per side for every ping. This beam-forming method overcomes the along track resolution and towing speed limitations of traditional side scan sonar systems.

Vessel 2802 is equipped with a hull-mounted sled to which the SSS towfish is attached. The Klein 5500 sonar system tow fish operates at a frequency of 455 kHz with two transducer arrays (port & starboard). Each Klein 5500 transducer simultaneously forms five dynamically focused beams per side, allowing increased resolution along track (20–36 cm) and across track (7.5-30cm) dependant upon range scale.

This hull-mounted configuration eliminates offset, layback, and heading errors associated with a towed system, thereby increasing the positioning accuracy of the processed imagery. An added benefit of this configuration is its ability to avoid entanglement with crab trap floats and operate in and around tight quarters (ex: piers and/or piles) as compared to the towed configuration.

The Reson 7125 MBES installed on vessel 2802 was operated simultaneously operated with the Klein SSS to provide a “skunk stripe” of bathymetry in the center of the SSS swath. When running the Reson 7125 and Klein SSS simultaneously crosstalk did occur between the two systems. To minimize this problem, the Reson 7125 was operated in the high-frequency 256 beam mode with aggressive filters applied to the outer beams which resulted in satisfactory nadir soundings.

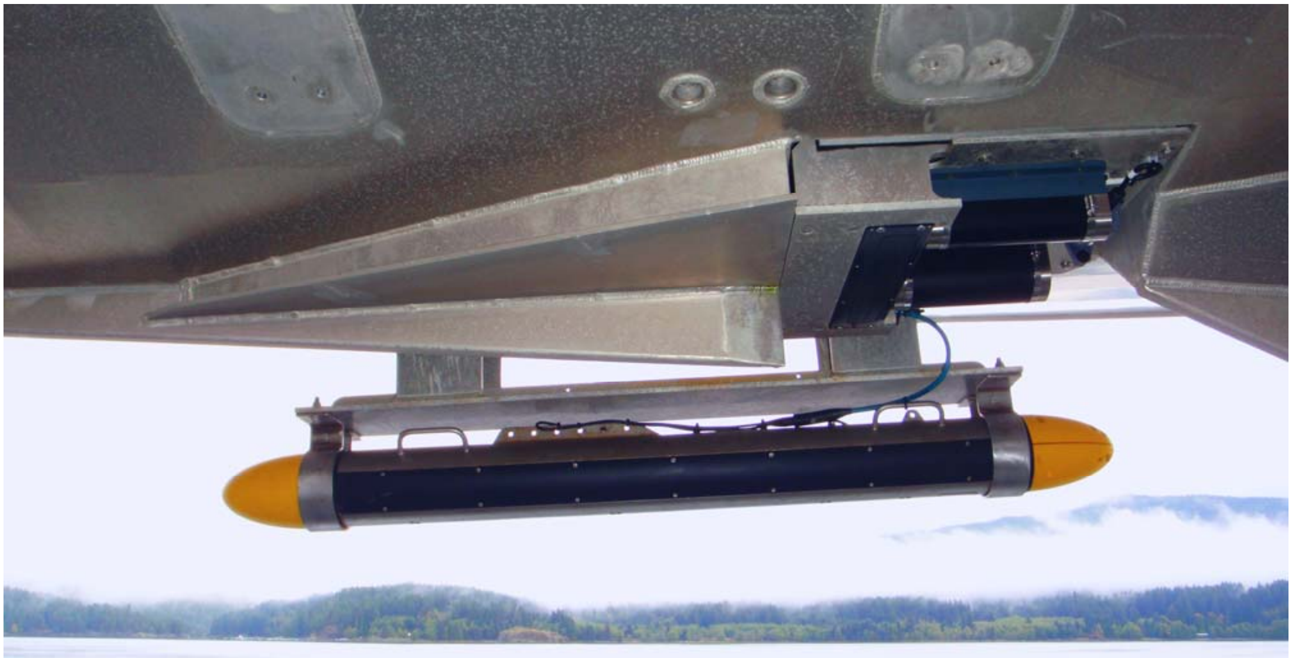


Figure 2 Klein 5500 side-scan sonar head, as installed on Launch 2802 (RA-5)

2. Multibeam Echosounder Backscatter

The Option 033 of the Reson SWMB systems used aboard 1101, 1021 and 1015 provide angle-independent imagery similar to fixed-mount side scan sonar (SSS). The Reson 7125 systems aboard 2801 and 2802 also collected 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. Due to a combination of increased RAW data file sizes when logging "snippet" data, space limitations with *Rainier's* current data storage, stability issues with the Reson 7125 and increases in storage use (due to the greater data logging rates of the 7125, C3D data, and full PosPac data), all Reson "snippets" logging was disabled beginning May 27th 2008.

Positioning Equipment:

1. Applanix POS MV 320

To measure and calculate position, vessels 1101, 1021, 2801, 2802 and 1015 are equipped with Applanix POS/MV 320 (version 4) Position and Orientation Sensors. 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 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.

Attitude Measurement Equipment:

1. Applanix POS MV

All *Rainier* SWMB launches (1101, 1021, 2801, 2802 and 1015) 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^o 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.

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. These data may be 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, although PPK was not used on this survey. In the rare event that position and attitude were not properly logged, these data were used to parse in position and attitude information to raw data files of the lines missing this information.

Sound Speed Measurement Equipment:

Vessel 2801 is equipped with a ODIM Brooke Ocean MVP30 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 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 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 SV casts 125 meters deep may be collected while in a typical underway survey mode of 7 knots cast depths of 50 meters are collected.

All other *Rainier* launches (1101, 1103, 1021, 2802, and 1015) 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.

Software:

Launches 1101, 1021, 1015, 2801 and 2802 recorded Reson shallow-water multibeam (SWMB) echosounder data, along with position and attitude data from the POS/MV using Triton-Elics’ ISIS software and logged in the Extended Triton Format (XTF). Reson bathymetry was logged in the XTF file in “0x18 RI_Theta” format.

Due to software stability issues between the Reson 7125 and Triton-Elics' ISIS software, *Rainier* began to experiment with collecting SWMB data with HYPACK. Launch 2802 recorded Reson 7125 Shallow water multibeam (SWMB) echosounder data, along with position and attitude data from the POS/MV using HYPACK Inc's. HYPACK / HYSWEEP software package. HYSWEEP is an optional add-on module to HYPACK hydrographic survey software. Data was logged in the ASCII (HSX Format) which includes full support for HYSWEEP survey features.

Launch 2802 recorded Klein side-scan-sonar data, along with position, heading, and layback, using Klein's SonarPro software. Data were logged in the Sonar Data Format (SDF), the native format of the SonarPro software. The SDF file format was chosen over that of the XTF format due to its ability to log true heading instead of just "course made good" values.

All SWMB data were processed using the CARIS Hydrographic Information Processing System (HIPS) and Hydrographic Data Cleaning System (HDCS) software version 6.1 for the Microsoft Windows environment.

HYPACK Inc's. Hypack was used for vessel navigation and line tracking during acquisition of SWMB data.

Sound velocity profiles were computed from raw pressure, temperature, and conductivity measurements using the program VelociWin, supplied by the NOS Hydrographic Systems and Technology Programs N/CS11 (HSTP).

A complete list of software and versions is included in the *2008 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.

Project Planning

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 to 2 years 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 lines 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 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 first hand 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.

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

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

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

and resolved if possible, and all submerged features are accurately represented. Shoreline verification (if applicable) and feature data are reviewed in the context of this bathymetry. Survey documentation (including the Descriptive Report) is generated in conjunction with this review process.

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 Isis and the on-screen display for the Reson SeaBat 8101 and 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.

Traditionally *Rainier* launches collected SWMB data by running on pre-planed line files with line spacing based on the anticipated depths. During project S-N922-RA-08, real-time coverage was used in lieu of line files on a trial basis. “Bite sized” polygons were planned to cover the assigned survey area of an entire sheet. These polygons are planned to run with the contours and polygons covering deeper areas are planned to be larger. In general polygons were sized such that a launch could expect to cover 3 to 5 polygons per day.

Once the polygons were drawn using either MapInfo or Caris Notebook, they were exported as shape files for either TritonMap or Hysweep. In the field, these polygons are displayed over the chart and in addition to plotting the SWMB swath coverage as it is collected. The launch coxswain uses this display to adjust the line as it is driving 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 collection saves time in both the pre-planning stage as well as eliminating the need for filling holidays during the next day of data collection.

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 6.1. 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 Error (TPE), 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. TPE values for tide and sound velocity must be entered for each vessel during TPE computation (see table #1).

- **Tide values measured** uncertainty value is the RSS of the error estimates associated with each six minute tidal value.
- **Tide values zoning** is provided in the Tide Requirements report for each project 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 two 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. *Rainier* used the Hydrographic Surveys Technical Directive 2007-2 recommended value of 4.0 m/s when 1 cast is taken every 4-hours. *Rainier* experience throughout project S-N922-RA-08 suggest that the relatively high value of 4.0 m/s better models sound speed error in an environment where fresh water lenses are common.
- **Sound speed value surface** for flat face transducers such as the Reson 8125 on vessel 1101 is 0.3 m/s due to use of the Odom Digibar Pro. The flat face Reson 7125 transducers on vessels 2801 and 2802 use a value of 0.15 m/s due to use of Reson SVP 71 fixed-mount sound velocity probe. All other launches that have no real time sound speed correctors at the transducer face use a value of 0.0 m/s.

Vessel	Tide values measured	Tide values zoning	Sound speed values measured	Sound speed values surface
1021_reson8101	0.01	0.12	4.00	0.00
1015_reson8101	0.01	0.12	4.00	0.00
1101_Reson8125	0.01	0.12	4.00	0.30
2801_Reson7125	0.01	0.12	4.00	0.15
2802_Reson7125	0.01	0.12	4.00	0.15

Table 1 (TPE Values for Tide and Sound Velocity)

High Caris TPE Values from Tilted 8125 data

Launch 1101's (RA-1) Reson 8125 sonar head is tilted 30 deg to starboard to allow for more efficient and more complete multibeam coverage in the near-shore area. However due to this configuration, the outer beams on the starboard side of the swath have extremely high Total Propagated Error (TPE) values when calculated by Caris HIPS. Especially in beams 235-240, TPE values from 2 to 10 m have been observed, typically in less than 8 m of water depth. Although expected to be higher due to a more oblique angle and beam spreading, the TPE values as calculated by Caris exceed the Hydrographer's expectations. Figure #3 shows an uncertainty model calculated by Dr. Brian Calder from UNH for a tilted Reson 8125 system at a variety of seafloor slopes.

Based on standard use of the system collecting near-shore data while running parallel to the shoreline, the slopes typically encountered are rarely less than 10 degrees. It is *Rainier's* opinion that these high TPE values are due to Caris' model of TPE calculation and do not reflect the quality of these soundings. A Caris HelpDesk Ticket (00802013) has been opened to address this issue. Please note that all *Rainier* submitted CUBE surfaces are finalized using the "Greater of the Two" of standard deviation and TPE as per the Field Procedures Manual section 4.2.6. Because the TPE of the soundings involved are so high, the resulting surface error values are also high - higher than would usually be acceptable. These inshore, outer-beam data have been thoroughly reviewed by *Rainier* personnel and using the near shore surfaces to update the charts irrespective of the surface error is recommended.

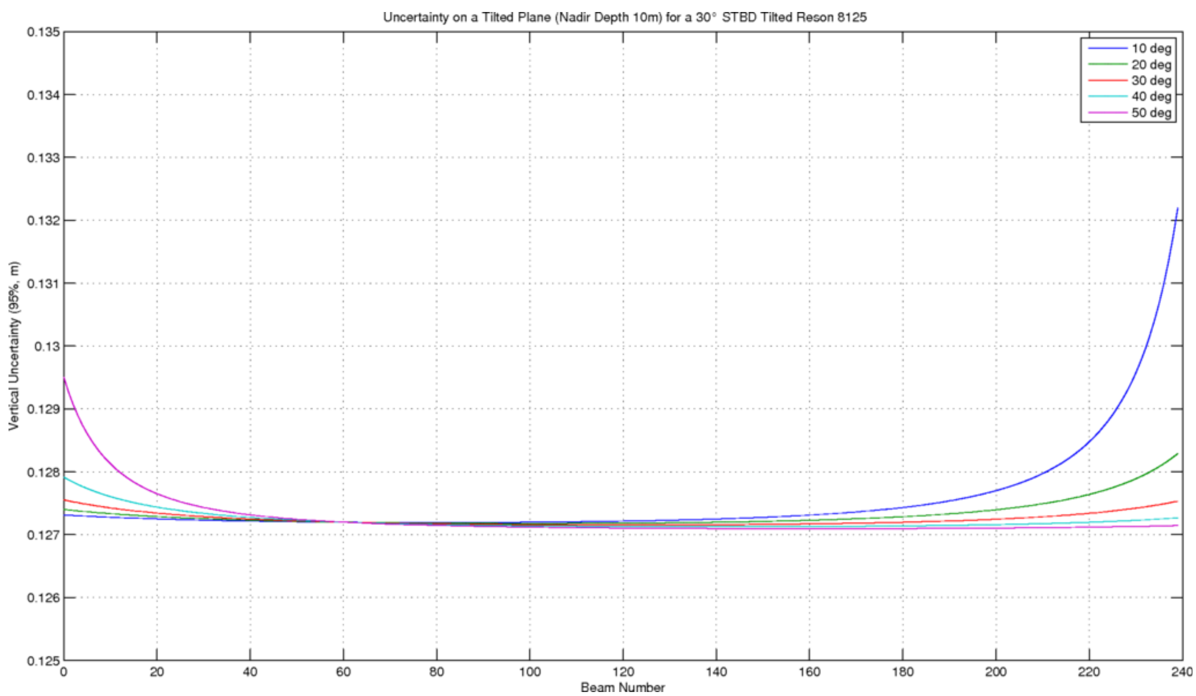


Figure 3 A graph showing the effect of seafloor slope on vertical uncertainty at 95% CI vs. beam number for a Reson 8125 system tilted 30 degrees with a 10m nadir depth. [source, Dr. Brian Calder]

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.

The exact behavior of CUBE is determined by the values set in the CUBE Parameters File (CUBEParams.xml). During the creation of CUBE surfaces the user is given the option to select parameter configurations which have been tuned by Hydrographic Systems and Technology Programs (HSTP) personnel to optimize performance of the CUBE algorithm (HSTD 2007-2). These parameters have been implemented by CARIS as "Deep" and "Shallow" options. The "Deep" configuration corresponds to the NOAA "Complete" survey requirements and is typically chosen for CUBE surfaces created for depths greater than 20-meters. The "Shallow" configuration corresponds to the NOAA "Object Detection" survey requirements and is typically selected for CUBE surfaces created for depths less than 20-meters. The CUBE Parameters File as tweaked by *Rainier* (CUBEParams_61.xml) is submitted with each survey as part of the digital data files.

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 (XTF or Hypack) to the HDCS data format.
2. If necessary parse PosPac data using HIPS “Load attitude and nav” tool (only if navigation or attitude data is missing from the raw data).
3. Load predicted tides.
4. Load and apply sound velocity files.
5. “Merge” data to apply position, attitude, vessel offsets, and dynamic draft correctors to bathymetry and compute the corrected depth and position of each sounding.
6. Compute TPE.
7. Filter data according to the following criteria:
    - Reject soundings with poor quality flags, (0 for Reson and 3 for Elac).
    - Reject soundings with TPE greater than the horizontal and vertical error limits specified in the NOS Hydrographic Surveys Specifications and Deliverables:

Horizontal Error > ±(5m + 5% of depth)

Vertical Error $> \pm\sqrt{\left[a^2 + (b * d)^2\right]}$, 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

8. Add data to a temporary boat-day field sheet for each sheet on which that boat acquired data.
    - Field Sheet naming convention: Hxxxxx_<vessel>_<DN> (e.g., H12345_1006_DN123)
    - Base surface are created in accordance with the depth ranges set forth in table #2.
    - Multiple surfaces of differing resolutions may be created dependant upon the range of depth encountered during that particular boat day.
    - Boat-day field sheets are kept as small as possible since CARIS allocates memory for any empty space which slows down processing. Field sheets are created big enough to cover the full extents of the MBES swaths of the day’s data, but not bigger than necessary.

Depth Range Filtering	CUBE Surface Resolution	Advanced Configuration
0 – 21.5 m	1.0 m	shallow
18.5 – 52 m	2.0 m	deep
46 – 115 m	4.0 m	deep
103 – 450 m	8.0 m	deep
410 m +	16.0 m	deep

Table 2 Depth range vs. CUBE surface resolution

Practical experience aboard *Rainier* suggests that CUBE surfaces generated with these resolutions and depth ranges (see Table 2, above) are sufficient for “complete coverage” surveys that are required to detect 2 x 2 x 2 m objects from 0 to 20 m. Higher resolution surfaces would burden the processing pipeline with resolutions so high that they are neither supported by the actual data nor practical in terms of computational time or file size. Still unresolved problems with the CARIS multiple resolution algorithm results in poor junctions at the resolution steps but an overlap of ~15% of the depth (i.e., +/-7%) appears to yield usable results for cleaning and planning purposes.

It has been observed aboard *Rainier* that different fieldsheets which cover the same dataset may produce widely different CUBE surfaces. As a result, a set of data which has been cleaned to remove all fliers for one fieldsheet may produce an entirely different set of fliers for a different fieldsheet that covers the same area. This problem only gets worse when multiple surfaces of differing resolutions are involved for each fieldsheet. In an effort to eliminate this problem, cube surface resolution values of 1, 2, 4, 8 and 16 meters were chosen. Since these resolution values are even multiples, all of the surfaces produced for a given fieldsheet will have the nodes of all surfaces co-located.

Although this approach helps to curb the flier problem within a single fieldsheet, multiple overlapping fieldsheets may still cause problems since one fieldsheets co-located nodes will probably not match the exact same geographic position as another fieldsheets nodes. This problem may be resolved if the easting and northing of the northwest corner of all fieldsheets created is evenly divisible by sixteen. Caris HIPS uses the northwest corner to initiate the nodes of a field sheet. Unfortunately, HIPS won't let you set the values of the northwest corner directly but indirectly this can be accomplished by editing both the easting and northing to be multiples of 16 in both the southwest and northeast corners during field sheet creation. *Rainier* strongly advises that any new fieldsheets created further down the processing pipeline follow this procedure to minimize the appearance of new fliers.

The following options are selected when CUBE surfaces were created:

- **Surface Type** – CUBE
- **IHO S-44 Order** – Order 1
- **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** – “Shallow” is selected for 1m resolution surfaces, “Deep” is selected for all other surfaces.

Preliminary data cleaning is performed on single resolution surfaces (1, 2, 4, 8 and 16 m, as required – using table #2 for guidance) for each boat/day field sheet. The “shallow” CUBE parameter is selected 1m surfaces, “deep” for 2-16m surfaces. Each surface is masked to the appropriate 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 >18.5 AND Depth <52

Preliminary data cleaning is performed daily using the Boat-Day CUBE surface as a guide for "directed editing". 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.

- 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 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, it is added to the affected "constant maintenance" CUBE surfaces. These "constant maintenance" CUBE surfaces are a group of fieldsheets tiled in such a way as to keep the CUBE surfaces small enough for rapid computation. These CUBE surfaces use the "*Rainier* standard" set of grid depth-resolution ranges (see Table #2 above) and are used to ensure bottom coverage and plan additional lines. In addition these "constant maintenance" CUBE surfaces are 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. Each sheet manager is responsible for setting up the constant maintenance field sheets. There will be approximately 6 to 8 for each survey sheet, named sequentially. (e.g. "H12345_A", "H12345_B", etc.)

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_Launch_8m.
- The surface is created as a single resolution CUBE surface at 8m resolution.
- The CUBE "Deep" is selected.

Final review of the "constant maintenance" CUBE Surface is left to the Mentor 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 is often defined as three times the beam footprint size for a particular echosounder and depth combination. In practice, RAINER adheres to a table of resolutions and depth ranges gained through practical experience in “typical” survey areas, and a working knowledge of bottom coverage capabilities of each echo sounding system in use. These resolutions are also based on assumed sonar system selections for each depth regime and practical data processing limitations. Typically, deeper areas are gridded at a coarser resolution than shoaler areas where the data density is greater.

Another shortcoming exists in CARIS that limits CUBE surfaces to a maximum of approximately 25 million nodes. This upper bound is imposed to keep CUBE surface processing within the 2 GB of physical memory installed on most *Rainier* workstations. Exceeding this limit has been shown to dramatically increase processing time and software crashes as the system swaps data to and from virtual memory. This node limit is generally not a problem at the coarser resolutions, but surveys requiring 1m or finer resolution surfaces often must be subdivided into several field sheets to keep the respective CUBE surfaces under this limit. The field sheet layout and CUBE surface resolutions are described for each survey in the Descriptive Report.

Each resolution-specific field sheet and its CUBE surface share a unique name, according to the following convention:

H<registry #>_<resolution in meters>M_<letter designation, if necessary>

(EX: “H12345_2M” refers to the two-meter resolution surface of survey H12345 and “H54321_1M_C” would be the third field sheet necessary to cover the area of H54321 at one-meter resolution.)

Once the collection of field sheets 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 CUBE surfaces are then combined at the coarsest resolution used to create the final combined CUBE surface. The final, combined CUBE surface should be named Hxxxxx_Final_Combined_Xm and be created in the survey wide field sheet Hxxxxx.

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 fieldsheet 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, a number of cross-lines greater than 5% of mainscheme 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

No traditional shoreline verification was conducted for project S-N922-RA-08 since the single sheet assigned lies almost entirely offshore with the exception of the extreme northeast corner. This corner of the sheet abuts North Jetty which was entirely investigated with SWMB. Source shoreline data for this project was supplied by N/CS31 in a single Composite Source Shoreline file in S57 000 format (0_1FME01.000).

C. CORRECTIONS TO ECHO SOUNDINGS

Sound Velocity

Sound velocity profiles were acquired with SeaBird Electronics SeaCat SBE 19Plus Conductivity, Temperature, and Depth (CTD) profilers (S/N 4039, 4114, 4343, and 4443). Raw conductivity, temperature, and pressure data were processed using the program VelocWin which generated sound velocity profiles for CARIS in the .SVP format. Calibration reports and dates of the SeaCat profilers are included in the *2008 NOAA Ship Rainier Hydrographic Readiness Review Package*.

The speed of sound through the water was determined by a minimum of one cast for every four hours of SWMB acquisition in accordance with the Standing Project Instructions and 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 Odom Digibar Pro mounted on vessel 1101 and the Reson SVP 71 mounted on vessels 2801 and 2802.

Sound velocity profiles were also acquired with the ODIM Brooke Ocean MVP30 Moving Vessel Profiler mounted on launch 2801 and processed using the program VelocWin version 8.91 which generated sound velocity profiles for CARIS in the .SVP format. The multiple profiles collected throughout the day are automatically concatenated into a single .SVP file.

The Reson 8125 SWMB system utilized on vessel 1001 requires a sound velocity probe to be interfaced with the sonar processor for use in projector steering computations. An Odom Digibar Pro, model db1200 velocimeter is utilized to feed a real time SV value is feed directly into the 8125 system.

The Reson 7125 SWMB systems utilized on vessels 2801 and 2802 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.

Sound velocity profiles for CARIS were concatenated into a sheet-wide file in order of ascending time/date and saved in the root directory of each sheet's SVP directory. A naming convention of H*xxxxx*_Concat.SVP was used where H*xxxxx* is the sheet's registry number (Ex: **H11292_Concat.SVP** is the concatenated SVP file for sheet H11292). This concatenated file was then applied to all HDCS data collected with the option **Nearest in distance within time (4 Hours)** selected under the **Profile Selection Method**.

Occasionally the digibar or SVP 71 experienced problems due to kelp or bubbles interfering with the sound velocity sensor. These blowouts will cause CARIS to refuse to converting Reson data. Basically, if the sound speed is too low or too high, Reson will not accept it - so the Reson data will continue to look good, but CARIS will not convert it This problem may be circumvented by running the HSTP developed macro SetXTFReson8125ss.py. This macro allows a user entered sound speed to supercede the erroneous value in the Reson XTF packet. Since the beamforming is not done in CARIS, the exact value of the user entered sound speed is not critical, so long as it is in the range which CARIS will accept. The macro creates a new xtf file (line_yyyy.xtf, where yyyy is the sound speed input, (should be 1500). This new file is then converted as normal.

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 *2008 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
1101	April 2008	Surface analysis	April 3,2008	Lake Washington, WA
1021	April 2008	Optical Level	March 28, 2008	Lake Washington, WA
2801	April 2008	Surface analysis	April 23,2008	Yukon Harbor, WA
2802	April 2008	Surface analysis	April 16,2008	Yukon Harbor, WA
1015	July 2008	Optical Level	April 5, 2007	Lake Washington, WA

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

Settlement and squat observations were conducted for launches 1101, 2801 and 2802 using a surface analysis method. The procedure follows the one outlined in the FPM (1.4.2—Vessel Dynamic Offsets). The same line run repeatedly was used to acquire the data. After the initial first line was run at idle, the speeds thereafter increased at 200-RPM increments. Finally settlement and squat speed curves were derived by querying three pre-selected target areas using surface differencing was used in Fledermaus and graphing the change of apparent depth at different speeds.

The optical level method was conducted for launches 1021 and 1015. The procedure followed that outlined in the FPM (1.4.2—Vessel Dynamic Offsets). One line drawn in Lake Washington was used to acquire the data. After the initial first line was run at 1000RPM, the speeds thereafter increased at 200-RPM increments. The vessel was run perpendicular to the pier since running parallel to the pier made reading the rod very difficult. Port and starboard values were averaged at rest and for each speed ran. The difference between the average at rest readings and the average of the port and starboard underway readings produced the values for the settlement and squat speed curves. The settlement and squat values obtained in 2007 were retained for vessel 1015 since it is configured with the exact same hardware as used in 2007.

Due to the fact that *Rainier* acquired two new launches and a SWMB system was installed for the first time on launch 1101, arrangements were made for personnel from the National Geodetic Survey's Geodetic Services Division to conduct spatial relationship surveys. Vessels 1101, 2801, and 2802 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. These measurements, in addition to dimensional blueprints and technical schematics from sonar manuals were used to determine each vessels' offsets.

Vessel offsets and static draft for vessels 1021 and 1015 were measured using both steel tapes and a LEICA laser distance meter. One notable configuration change from 2007 include an adjustment on 1021's Reson transducer to keep it from rubbing when retracted. In most cases, measurement values obtained were within a few centimeters of historic values and these were retained. In the case of larger differences, the new values superseded the old.

Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVFs). Survey platforms with more than one acquisition method have a separate HVF associated with each individual acquisition system aboard. Each of these HVFs contains sensor offset and dynamic draft correctors that pertain to this single acquisition system.

Hysweep data collected by vessels 2801 and 2802 required the creation of separate HVFs.. For ISIS data the bias values are entered under in the *SVP 1* sensor while the Hysweep bias values are entered in the *Swath 1* sensor. This difference is due to how the bias values must be applied in the processing pipeline with ISIS data vs Hysweep data. Reson 8101 and 8125 HVFs are interchangeable between ISIS and Hysweep.

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 included in the *2008 NOAA Ship Rainier Hydrographic Readiness Review Package*. The HVFs themselves are submitted with the digital HDCS data.

The following table lists each HIPS Vessel File used for this project:

HVF name	**Survey Vessel & System Type**
1015_Reson8101_HVF	Jensen hull 1015, SWMB using hull mounted Reson 8101
1021_reson8101_HVF	Jensen hull 1021, SWMB using swing-arm mounted Reson 8101
1101_Reson8125_hvf	Jensen hull 1101, SWMB using hull mounted Reson 8125
2801_Reson7125_HF_256beams	Jensen hull 2801, SWMB using Reson 7125, 400kHz, 256 beams
2801_Reson7125_HF_512_Hysweep	Jensen hull 2801, SWMB using Reson 7125, 400kHz, 512 beams, collected using Hypack's Hysweep acquisition software
2801_Reson7125_HF_512beams	Jensen hull 2801, SWMB using Reson 7125, 400kHz, 512 beams
2801_Reson7125_LF_256beams	Jensen hull 2801, SWMB using Reson 7125, 200kHz, 256 beams
2802_Klein5K_100_HVF	Jensen hull 2802, 100% SSS using hull mounted Klein 5500
2802_Klein5K_200_HVF	Jensen hull 2802, 200% SSS using hull mounted Klein 5500
2802_Reson7125_HF_256beams	Jensen hull 2802, SWMB using Reson 7125, 400kHz, 256 beams
2802_Reson7125_LF_256beams	Jensen hull 2802, SWMB using Reson 7125, 200kHz, 256 beams

Table 5 List of HVFs used for project S-N922-RA-08

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. Each vessel's TrueHeave files were saved in the "POS" folder of the CARIS preprocessed data drive (ex: H:\OPR-O112-RA-06_Sitka\H11128\POS\1016\DN148 contains TrueHeave data collected by vessel 1016 on day number 148 for sheet H11128). In the event of a computer crash, a new POS file must be created. Multiple POS files have their names appended with "A", "B" and so on so that the order they were collected in could later be determined. After regular CARIS data conversion this TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw data.

To avoid CARIS problems in applying true heave it is now standard procedure to start TrueHeave logging at least 3 minutes before starting bathymetric data collection, and letting it run for at least 3 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 collection time of bathymetric data. If there is still 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.

In the event that the POS file refuses to load it is also possible to apply POSPac data. Although this process is labor intensive, it did provide a fall-back method to reduce heave artifacts.

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in the *2008 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 from station Westport, Washington (944-1102) using the tide file 9441102.tid. The predicted water level data from this tide station was applied to the survey depths in CARIS using height ratio and time correctors from the CO-OPS provided zone definition file, N922RA2008CORP.zdf supplied with the Hydrographic Survey Project Instructions.

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.

For project S-N922-RA-08, soundings were reduced to Mean Lower-Low Water (MLLW) using verified observed water levels from station Westport, Washington (944-1102) using the tide file 9441102.tid. The water level data from this tide station was applied to the survey depths in CARIS using height ratio and time correctors from the CO-OPS provided zone definition file, N922RA2008CORP.zdf supplied with the Hydrographic Survey Project Instructions.

Refer to the Horizontal and Vertical Control Report for specific information on the tidal gauges used in during this project and 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 2008 edition), NOS Hydrographic Surveys Specifications and Deliverables (May 2008 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.

Donald W. Haines, CAPT/NOAA
I am approving this document
2009.04.13 19:29:03 -07'00'

Approved and Forwarded: ______________________________

Donald W. Haines
Captain, NOAA
Commanding Officer

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

James B Jacobson
I am the author of this document
2009.04.13 10:06:07 -07'00'

Chief Survey Technician: ______________________________

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

I have reviewed this document
2009.04.13 16:03:41 -07'00'

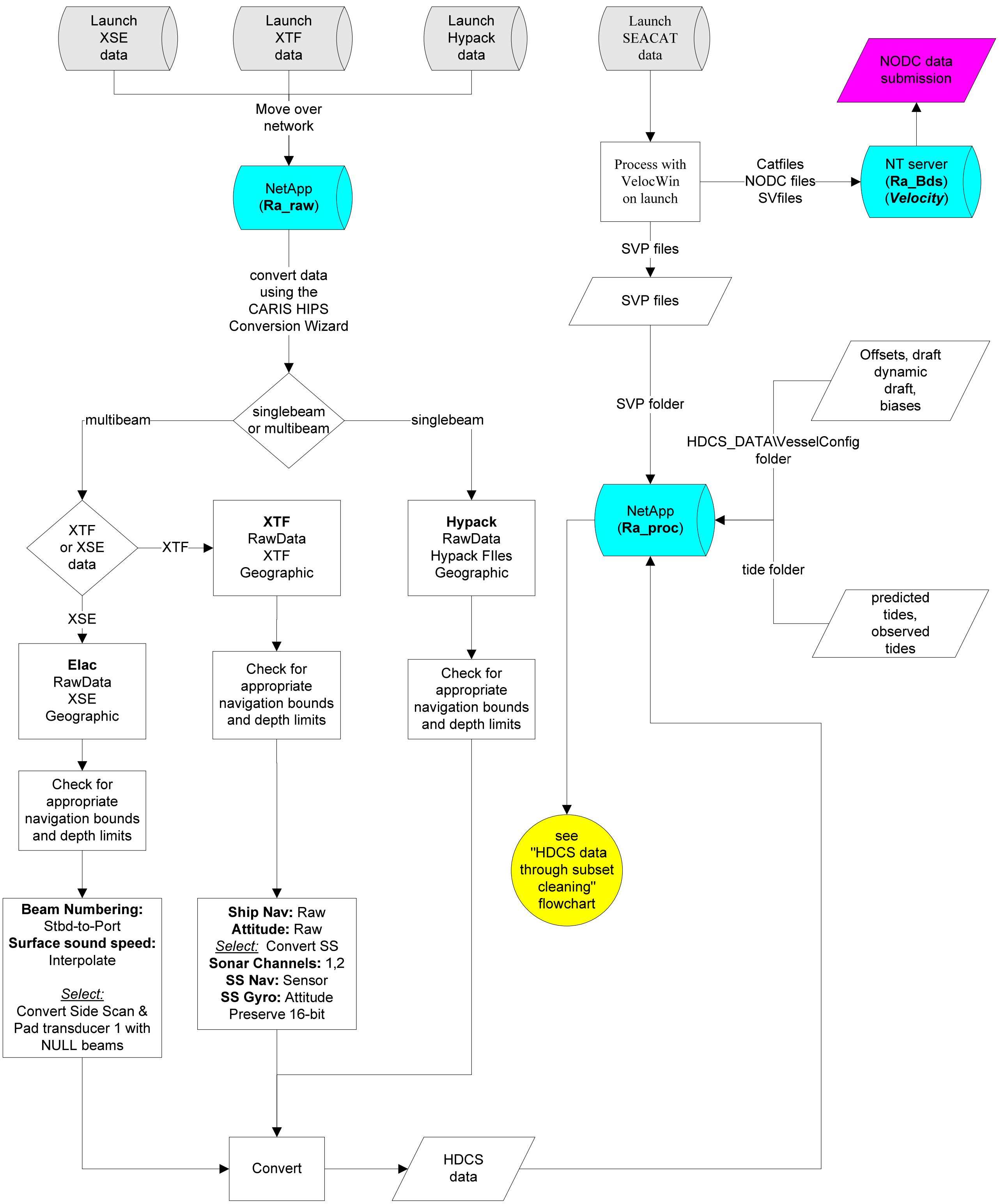
Field Operations Officer: ______________________________

Charles J. Yoos
Lieutenant, NOAA

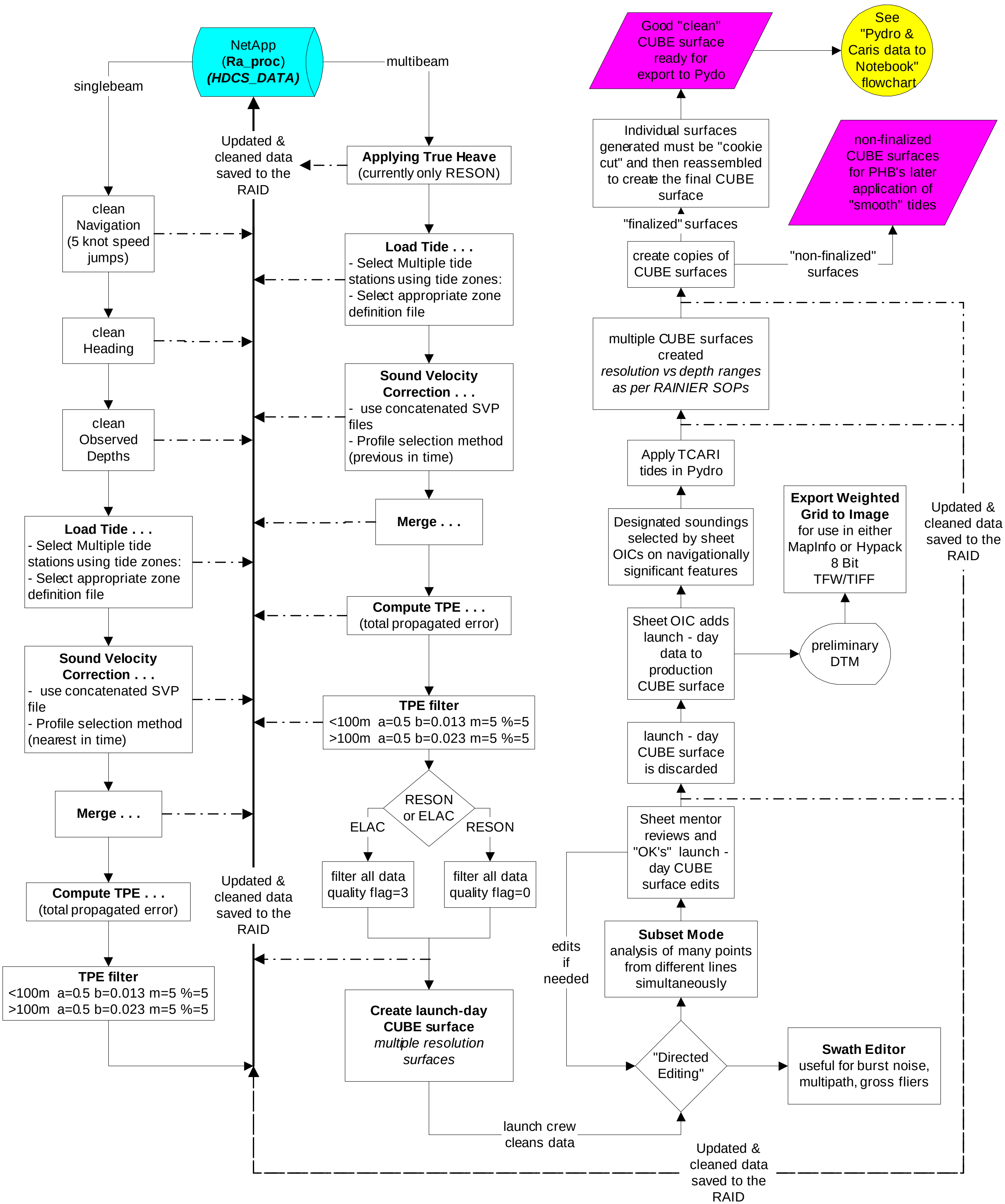
APPENDIX I

Data Processing Flow Diagrams

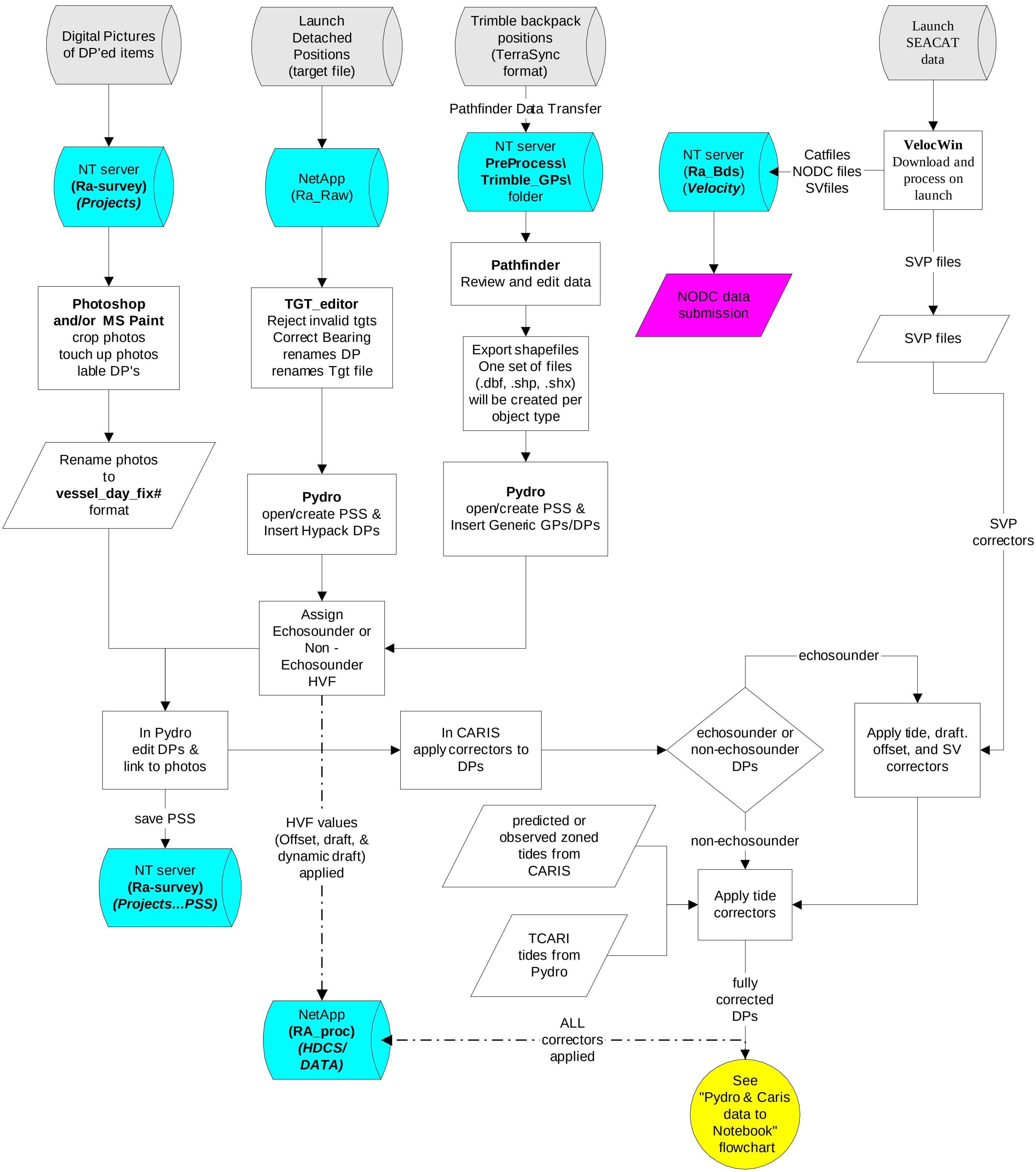
Raw sounding data to HDCS



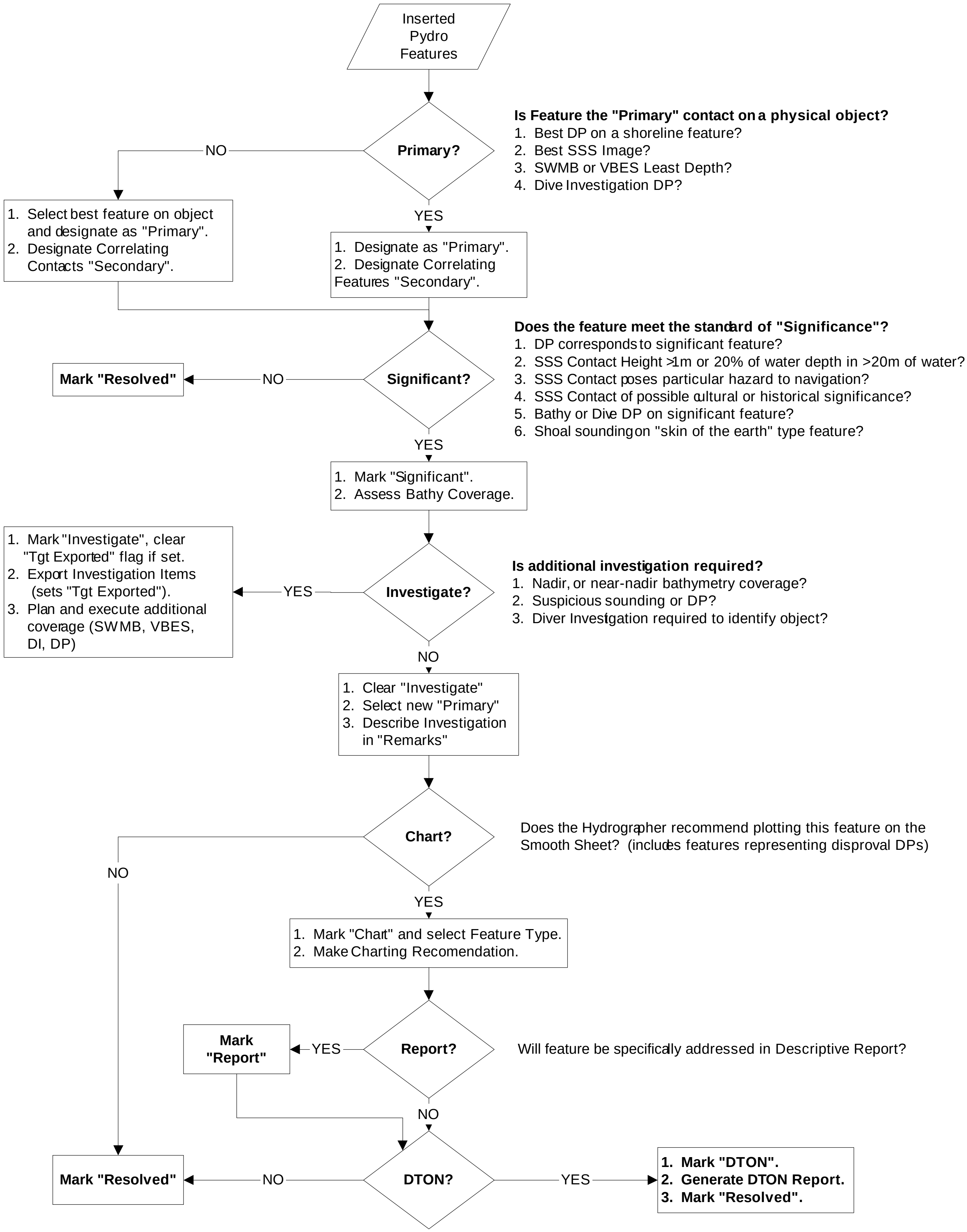
HDCS data through subset cleaning



Detached Position processing
(Raw DP's to Pydro)



Detached Position processing in Pydro



Pydro & Caris data to Notebook