Data Acquisition and Processing Report
NOAA Ship RAINIER (s221)

OPR-N161-RA-05
Approaches to Anacortes and Bellingham, Washington
Hydrographic Letter Instructions dated March 15, 2005
Chief of Party: Commander Guy T. Noll, 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 sheets of this project. Data were acquired by the following RAINIER survey launches:

Hull Number	Vessel type
1101	29 foot Jensen jet drive survey launch
1103	28 foot Munson jet drive work boat
1021	29 foot Jensen survey launch
1016	29 foot Jensen survey launch
1006	29 foot Jensen survey launch
1015	29 foot Jensen survey launch

Vessels 1021, 1016, 1006 and 1015 are used to acquire shallow-water multi-beam (SWMB) data and sound velocity profiles. Vessels 1101 and 1103 are used to collect vertical-beam echosounder (VBES) data and detached positions. Vessels 1101 and 1015 are also used to collect side-scan-sonar (SSS) data. Any vessel may be utilized for collecting bottom samples. No unusual vessel configurations or problems were encountered on this project. Vessel descriptions and offset measurements are included in the NOAA Ship RAINIER 2005 Field Season Hydrographic Systems Certification Report.

Six different categories of echosounder systems were utilized for project OPR-N161-RA-05. 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 Standing Project Instructions, the Hydrographic Letter Instructions, 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 *2005 Hydrographic Systems Certification Report*

Sounding Equipment:

1. RESON 8101 Launch Shallow Water Multi-Beam (SWMB)

Vessel 1021 is equipped with a Reson SeaBat 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 1006 is equipped with a hull-mounted Reson SeaBat 8101. Both of these Reson SeaBat 8101s are equipped with option 033, Angle-Independent Imagery, and option 040, Extended Range Projector. The SeaBat 8101 is a 240 kHz multi-beam 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 200 meters, with varying range scale values dependent upon the depth of water and across-track slope.

2. RESON 8125 Launch Shallow Water Multi-Beam (SWMB)

Vessel 1016 is equipped with a hull-mounted Reson SeaBat 8125, with option 033, Angle-Independent Imagery. The SeaBat 8125 is a 455 kHz multi-beam system that uses high frequency focused near-field beam forming to measure relative water depths across a 120^o swath, consisting of 240 individual 0.5^o x 1.0^o beams. This system was used to obtain full-bottom coverage in depths generally 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.

3. ELAC 1180 Launch Shallow Water Multi-beam (SWMB)

Vessels 1016 and 1015 are equipped with a hull-mounted Elac 1180, which is a single frequency (180 kHz), multi-beam echosounder system for shallow and intermediate water depths. The transducer assembly consists of two flat-faced transducers, one starboard and one port, each mounted at a 38° angle from horizontal. Echosounding is achieved using a Rotating Directional Transmission (RDT) method where sound is directed utilizing the directional gain of the complete transducer array. Sonar transmission occurs across adjacent sectors in a 3-step "subfan" process. Out of each of the 3 subfans within a sector, the receiving beamformer calculates 3 slightly overlapping beams each 1.5^o wide with a spacing of 1.25^o, for a total of 9 beams per sector. There are 7 fanwidth settings possible, the maximum of which (153.5º) utilizes 7 sectors, for a maximum total of 126 beams within a "virtual swath". RAINIER personnel typically operate the Elac 1180 on a swath width of 131º (116 beams) or 108º (90 beams), depending on water depth, sea state, data quality, and coverage requirements. Surface sound velocity was measured using an Odom Digibar Pro model db1200 velocimeter, directly interfaced with the Elac data acquisition workstation.

Because the RDT beam forming method described above requires three ping cycles to fully ensonify the coverage swath, the Elac 1180 cannot meet the coverage and object detection requirements specified in the NOS Hydrographic Surveys Specifications and Deliverables currently in effect while maintaining a reasonable survey speed. Hydrographic Surveys Division has been informed of this deficiency, and RAINIER will continue to operate this legacy system until funds are available for its replacement. In the interim, the Elac 1180 is not utilized as the sole means of bottom coverage in water depths less than 100 m. The Elac 1180 is occasionally used in shallow waters where few features are expected to provide bathymetry to accompany 200% side scan sonar coverage, or main scheme bathymetric coverage in depths between 40 and 100m. When utilized in this depth regime, all significant features indicated by the Elac are fully developed with a high resolution multi-beam sonar such as the Reson 8101 or 8125.

4. Klein 3000 Side Scan Sonar (SSS)

Vessel 1101 tows the Klein 3000 sonar system which consist of a towfish, towcable, a transceiver/processor unit (TPU), and a PC for system control, data logging, and data viewing. A new transducer design allows simultaneous dual frequency operation at 132 kHz and 445 kHz.. Superior imagery is produced due to the incorporation of high resolution circuitry recently developed for the Klein 5000 multi-beam focused sonar. Fifteen different range scales are available, varying between 25 to 1,000 meters. Beams are formed 40 degrees wide on the vertical and 0.7 degrees at 132 kHz (0.21 degrees at 445 kHz) on the horizontal.

Vessel 1101 is also equipped with a hydraulic winch powered by a portable gasoline engine and spooled with approximately 150 meters of 0.322" armored Rochester cable. The tow cable at the winch is connected to a deck cable through a slip ring assembly mounted coaxially on the winch. Cable-out is controlled remotely near the acquisition station and is monitored with a 3ps Inc. SD41 cable counter. This sensor measures the side scan towfish cable out by counting the number of revolutions of the towing block on the J-frame. The length of cable deployed is computed automatically and output via serial message directly into the Klein TPU.

5. Klein 5000 Side Scan Sonar (SSS)

The Series 5000 sonar system consist of a towfish, a transceiver/processor unit, and a PC for system control, data logging, and data viewing. The Klein 5000 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 1015 is equipped with a hull-mounted sled to which the SSS towfish is attached. The Klein Series 5000 sonar system tow fish operates at a frequency of 455 kHz with two transducer arrays (port & starboard). Each Klein 5000 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.

6. Launch Vertical Beam Echosounder (VBES)

Vessels 1101 and 1103 are equipped with a Knudsen Engineering Limited 320M, which is a dual frequency (100 kHz, 24 kHz) digital recording vertical-beam echo sounder with an analog paper record. The beam widths for the high and low frequency are 7° (conical) and 25°by 40° (rectangular) respectively. Soundings were acquired in meters for both frequencies, with the high frequency sounding recorded as the primary frequency in the acquisition software (Hypack). The low frequency was often disabled in shallow water because it distorted the echosounder trace.

VBES data were acquired in near shore areas to define the Navigational Area Limit Line (NALL) and determine the inshore limit of hydrography. VBES data were also acquired over offshore reefs and shoals, in depths generally ranging from 0 to 20 meters. Sounding lines were run perpendicular to depth contours at a line spacing sufficient to determine general near shore contours, with splits run at a reduced line spacing to develop shoal areas that were deemed too shallow for the safe or effective use of a vessel equipped with SWMB. In addition, in some cases VBES data were acquired as cross lines for comparison to main scheme multi-beam echosoundings.

6. Diver Least-Depth Gauge

A diver least-depth gauge (DLDG) was utilized to obtain least depths over selected rocks and features. The DLDG utilized by RAINIER is a Mod III (S/N 68332), last calibrated in March 2005. A copy of the calibration report is included in the *2005 Hydrographic Systems Certification Report*. The depth gauge measures pressure, and is combined with a CTD profile using VelociWin software to determine depth. These depths were processed in Pydro along with the corresponding detached position (DP).

In addition to the Mod III, Rainier is also equipped with an In-Situ miniTROLL "Advanced". This system has been approved for experimental use by the Hydrographic Systems and Technology Programs office. The miniTROLL features an internal data logger with a pressure/level sensor and is completely self-contained in a 316-Stainless Steel body. The integrated silicon strain-gauge pressure sensor claims an accuracy of ±0.1% over full pressure and temperature range, or 0.05% @ 15°C. Data is recorded at a minimum sampling rate of

0.5 seconds and saved in internal memory capable of storing 80,000 data points. This data is then downloaded with a PC using the included Win-Situ software.

7. 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 2005. Calibration reports are included in the *2005 Hydrographic Systems Certification Report.*

Side Scan Sonar & SWMB Systems

The Option 033 of the Reson SWMB systems used aboard 1006, 1016, and 1021 provide angle-independent imagery similar to fixed-mount side scan sonar (SSS). The ELAC SWMB systems used aboard 1016, 1015 and the RAINIER also provides a very low-resolution digital SSS record of the multi-beam swath. This SSS imagery is primarily used during processing of the multi-beam 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. Reson "snippets" imagery was also recorded at acquisition and is present in the raw data, but is 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 reduce the efficacy of processing these data.

Positioning Equipment:

Vessels 1101 and 1103 are equipped with Trimble DSM212L GPS receivers. The DSM212L is an integrated 12-channel GPS receiver and dual-channel DGPS beacon receiver. The beacon receiver can simultaneously monitor two independent U.S. Coast Guard (USCG) DGPS beacons. There are three modes: Auto-Range, which locks onto the beacon nearest the vessel; Auto-Power, which locks onto the beacon with the greatest signal strength; and Manual, which allows the user to select the desired beacon. Additionally, the DSM212L can accept differential correctors (RTCM messages) from an external source such as a user-established DGPS reference station. The DSM212L was configured in the manual mode to use only correctors from the nearest USCG beacon, to go off-line if the age of DGPS correctors exceeded 20 seconds, and to exclude satellites with an altitude below 8 degrees.

The following parameters were monitored in real-time through Trimble's TSIPTalker software to ensure position data quality:

- number of satellites used in the solution
- horizontal dilution of precision (HDOP)
- latency of correctors
- beacon signal strength

Vessels 1021, 1016, 1006, and 1015 are equipped with TSS POS/MV 320 (version 3) 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 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:

Vessel 1101 is equipped with a TSS Meridian Surveyor gyrocompass and TSS DMS-05 attitude sensor. These sensors were interfaced together and with GPS to aid the heading and attitude solutions. The Meridian Surveyor is capable of measuring heading to an RMS accuracy of ±0.2° x secant of latitude. The DMS-05 measures attitude to an RMS accuracy of 0.04°, and heave to the greater of ±5cm or 5% of the heave amplitude. The heave bandwidth filter on the DMS-05 was set to "short", which corresponds to an 8 second period.

Vessel 1103 was equipped with a TSS DMS-05 configured as on 1101, but no heading sensor. GPS Course Over Ground (as provided by the NMEA VTG string) was used for heading on this vessel.

RAINIER's SWMB launches (Vessels 1021, 1016, 1006 and 1015) are equipped with TSS POS/MV Model 320 version 3 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.

Software:

Launches 1021, 1016, and 1006 recorded Reson 8101 and 8125 Shallow-water multi-beam (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.

Launch 1015 recorded Elac multi-beam echosounder data, along with position and attitude data, using Elac's Hydrostar Online software. Data were logged in the Hydrostar exchange format (XSE) produced by version 3.4.0.1 of the Hydrostar software.

Launches 1101 and 1015 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 converted from raw form to HDCS format using the CARIS Hydrographic Information Processing System (HIPS) and Hydrographic Data Cleaning System (HDCS) software version 5.4 for the Microsoft Windows environment.

All SSS data were converted from raw form to HDCS format using the CARIS Sonar Image Processing System (SIPS) and the Side Scan Editor software version 5.4 for the Microsoft Windows environment.

All VBES data were acquired using Coastal Oceanographic's HYPACK MAX version 02.12a, in the "RAW" format. VBES data were processed using CARIS HIPS for the Microsoft Windows environment.

Post acquisition processing of all HDCS format data was accomplished using the CARIS Hydrographic Information Processing System (HIPS) and Hydrographic Data Cleaning System (HDCS) software versions 5.4 and 6.0 (after 3/14/2006) for the Microsoft Windows environment.

Coastal Oceanographic's HYPACK MAX was used for vessel navigation and line tracking during acquisition of SWMB data. HYPACK MAX was also used to quick mark targets that were processed as detached positions using Pydro supplied by the NOS Hydrographic Systems and Technology Programs N/CS11 (HSTP).

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 NOAA Ship RAINIER 2005 Field Season Hydrographic Systems Certification Report. 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 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 days 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 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) are generated in conjunction with this review process.

[1] "NOS Hydrographic Surveys Specifications and Deliverables", "OCS Field Procedures Manual", "Standing Project Instructions", 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.

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.

Multi-beam Echosounder Data

Shallow-water multi-beam 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 8125 sonar systems. The Elac HydroStar online bathymetry data display was monitored in real-time for the Elac 1180. Adjustable user parameters common for all sonars are range scale, power, gain, and pulse width. Swath width and bottom slope type are additional user parameters used during acquisition for the Elac sonar systems. 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.

RAINIER's primary bathymetric data review and quality control tool is the CARIS BASE (Bathymetry Associated with Statistical Error) surface as implemented in HIPS version 5.4. The BASE surface is a gridded bathymetric model of the seafloor with node attributes computed based on the horizontal and vertical uncertainty of each contributing sounding. This sounding 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. In HIPS, these 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 water level measurement and zoning, latency, sensor offset measurements, attitude and navigation measurements, draft measurements, and sound speed 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 default CARIS DeviceModels.xml has been extended by Coast Survey personnel to include error estimates for the Elac 1180 and 1050D multi-beam and Knudsen 320m and Ross 950 vertical beam echosounders.[3] This modified DeviceModels.xml file is include with the digital data submission.

Following acquisition, multi-beam 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 XTF or Elac XSE data to the HDCS data format.

[3] Although the error estimates for NOAA-specific equipment were derived from manufacturer data and empirical experience, CARIS HIPS currently uses a set of generic, conservative uncertainty estimates when computing TPE for non-standard echosounders, regardless of the contents of the DeviceModels.xml file. CARIS has indicated that they intend to extend the set of standard echosounders to include those used by NOAA and other surveyors in the near future, so the RAINIER-specific error model has been retained for potential recomputation of TPE at that time.

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 TPE.
6. Filter data according to the following criteria:
    a. Reject soundings beyond 60^o off-nadir to remove the noise and refraction errors possible in these outer beams from the final dataset.
    b. Reject soundings with poor quality flags, (0 for Reson and 3 for Elac).
    c. 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

7. Create a temporary Boat-Day BASE surface in the "Hxxxxx_Processing" field sheet.

The naming convention for these "temporary" BASE surfaces is "Launch Number_DnXXX" (Example: "1006_Dn095"). Typically these daily BASE surfaces are created with resolutions between 2 and 10 meters. When selecting the boat-day BASE surface resolution, the hydrographer attempts to match the final resolution called for the by the Field Procedures Manual (see Table 1, below) as closely as possible for the depth range encountered that day.

Two weighting schemes are available when creating the BASE surface. Swath angle weighting is based on a beam's intersection angle with the seafloor whereas uncertainty weighting is based on depth uncertainty. Uncertainty weighting was used exclusively in BASE surface generation because a swath angle-weighted grid does not contain an estimate of statistical error as does an uncertainty-weighted BASE surface.

Preliminary, daily data cleaning is performed using the Boat-Day BASE surface as a guide for "directed editing". Depth and Standard Deviation 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 base surfaces, especially the standard deviation base 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.

After initial cleaning is complete, the Boat-Day BASE Surface is reviewed by the Sheet Manager and

Mentor. At no point does the launch crew re-compute the Boat-Day BASE surface which could result in obscuring rejected soundings behind a now "smooth" BASE surface. Final review 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 without the need to re-compute the BASE Surface. The Manager is responsible for accepting the data and adding it to the appropriate production BASE surface in the "HXXXXX" Field Sheet. Specific data quality factors are discussed in the Descriptive Report for each survey.

The production BASE surface is used to ensure bottom coverage and plan additional lines. In addition the production BASE surface 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 Sheet Manager so that remedies can be found and applied before more data are acquired.

As the last step to finalize survey data, multiple BASE surfaces are gridded using different resolutions for different depth ranges in accordance with the Field Procedures Manual. 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 the guidance of the Field Procedures Manual (see Table 1, below), which includes suggested resolutions as a function of depth. These suggested resolutions are 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.

On occasion, the resolution of the BASE 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 BASE surface by greater than one half the allowable error under IHO S-44 Order 1 was considered inadequately captured by the BASE 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 BASE surface. To ensure that these features are properly represented, the shoalest point is flagged "designated" in CARIS. During the "finalization" process, the BASE 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 BASE surface, (i.e. a boulder field), the hydrographer may decide to produce higher resolution BASE surfaces to ensure that these features are being honored. Any such deviations from the Field Procedures Manual will be noted in that survey's Descriptive Report.

Unfortunately, at the time this document was generated, no tools existed in CARIS to easily vary grid resolution by depth in a single BASE surface. The individual grids generated must be "cookie cut" and then reassembled to create the final BASE surface from which depths are derived. This step can occur only after navigationally significant cultural features such as piles and wrecks have been flagged as "designated" so that the BASE surface will honor that sounding when the surface is finalized. If final approved water levels have not been received and applied to the data prior to submission, it is necessary for the field unit to submit both a finalized and un-finalized copy of each BASE surface. This dual submission is required since CARIS does not allow tides to be applied to BASE surfaces that have already been finalized and thus PHB would not be able to apply final approved water levels.

Another shortcoming exists in CARIS 5.4 that limits BASE surfaces to a maximum of approximately 25 million nodes. This upper bound is imposed to keep BASE 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 & ½ m resolution surfaces often must be subdivided into several field sheets to keep the respective BASE surfaces under this limit. The field sheet layout and BASE surface resolutions are described for each survey in the Descriptive Report.

Each resolution-specific field sheet and its BASE 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 BASE surface is finalized using the resolution and depth ranges specified in the Preliminary Field Procedures Manual (see table 1). All BASE surfaces are then combined at the coarsest resolution used to create the final combined BASE surface. The final, combined BASE surface should be named Hxxxxx_Final_Combined_Xm and be created in the survey wide field sheet Hxxxxx.

Depth Range Filtering	Final BASE Surface Resolution
0 - 15 m	0.5 m
14 – 30 m	1 m
29 – 60 m	2 m
59 – 150 m	5 m
149 m +	10 m

Table 1 Depth range vs. BASE surface resolution

These final BASE 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 BASE 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.

Vertical Beam Echosounder Data

Vertical Beam Echsounder data were converted to HDCS format by the same Batch Process procedure as multi-beam data. Sound speed and water level correctors were applied, and TPE calculated, and the data were filtered by the same uncertainty criteria as MBES data. However, due to the inherently sparse nature of VBES data, initial data cleaning is accomplished line by line in HIPS Single Beam Editor rather than by BASE Surface directed editing. VBES soundings were examined using the paper fathogram as a guide to identify and correct noise and missed depth digitizations. High frequency soundings were preferentially accepted over low frequency, except in cases where the fathogram or digitized depths suggested that the low frequency was more accurate. After this initial cleaning was complete, the data were incorporated into the final BASE Surfaces for comparison to MBES soundings and contribution to the final sounding set.

Side Scan Sonar Data

Side scan sonar lines are planned to run parallel to bottom contours, spaced according to the range scale appropriate for the water depth. Typically, to acquire two hundred percent coverage, 40 meter line spacing is used at the 50 m range scale, 60 meter line spacing is used at the 75 m range scale, and 80 m line spacing is used at the 100 meter range scale.

A towfish altitude of eight to twenty percent of the range scale is maintained during data acquisition. SSS altitude for towed operations is adjusted by the amount of deployed tow cable, and to a lesser degree by vessel speed. For hull mounted systems, this eight to twenty percent value can be maintained to some degree by adjusting the range scale.

Confidence checks are performed daily by observing changes in linear bottom features extending to the outer edges of the digital side scan image, features on the bottom in survey area, and by passing aids to navigation.

Depending on the requirements for the survey area, one of two methods can be utilized for SSS operations. The first method is used in areas where full MBES coverage has been obtained. Side scan sonar contacts are picked for further development only in areas of incomplete multi-beam coverage on man-made and/or ambiguous features. This method is also used to find man-made objects that could fall beneath the detection limits of SWMB.

With the second method, 100% or 200% side scan sonar coverage is obtained while simultaneously collecting either SWMB or VBES with the same vessel. While this method leaves significant gaps in sounding coverage, all significant SSS contacts are then selected and investigated further at the discretion of the Hydrographer. Item investigations are conducted by MBES developments. This method was typically used in the shoaler areas where acquiring 100% sounding coverage was not practical due to time constraints.

Although not specifically called for in the project instructions, both of the afore mentioned SSS methods were initiated by the Chief of Party and verbally approved by the Chief, Operations Branch, Hydrographic Surveys Division. Refer to individual Descriptive Reports for further information regarding the approximate boundaries of the regions covered with each SSS technique.

Following acquisition, Klein side-scan-sonar data were processed using CARIS HIPS and SIPS. Side scan sonar data was converted from *.sdf (SonarPro raw format) to HDCS. One hundred and two-hundred percent SSS are broken up by using different HVFs for each (ex: the HFV for 100% Klein 5000 SSS collected by hull 1015 is 1015_K5K_100_HVF, for 200% coverage 1015_K5K_200_HVF).

Processing side scan data begins with examining and editing with the Attitude Editor. Within the attitude editor SSS Gyro, Cable Out, SSS Sensor Height, and SSS Sensor Depth are available for editing. Cable Out and Sensor Depth are not applicable with Klein 5000 data since the system is hull mounted.

Next speed, distance, and course made good are examining and editing with the Navigation Editor. Once all edits are completed, towfish navigation must be recomputed only for towed SSS with the step **Select Process > Recompute Towfish Navigation…** During this step, tow point offsets (J-frame and cable out), fish depth, fish attitude, and water depth are used to calculate horizontal layback. This step is skipped for the Klein 5000 data since the fish is hull mounted.

After fish navigation is recalculated, it is the responsibility of the reviewer to verify that the side-scan properly tracked the bottom. If the side-scan bottom track dug into the bottom, or flew high digitizing on some noise, this must be corrected. There are 4 tools in CARIS to correct these problems: Manual digitize bottom, Automatic digitize bottom, Interpolate bottom, and Clear bottom (used only the bottom tracking is really bad). The Manual method was generally found to produce the best results. Only after bottom tracking has been corrected can the data be slant range corrected.

Side-scan imagery data are slant-range corrected to 0.1m resolution with beam pattern correction enabled. A sound speed of 1500 m/s and a flat seabed are also assumed.

The slant-range corrected side scan imagery data were then closely examined for any targets. Targets of interest are evaluated as potential contacts based upon apparent shadow length and appearance, particularly targets which do not appear to be natural in origin. Contacts are selected and saved to a contact file for each line of SSS data. A SSS contact was considered significant if:

- The shadow length indicated a contact height greater than 1m or 20% of water depth in >20m of water.
- The SSS Contact posed a particular hazard to navigation.
- The SSS Contact appeared to be of possible cultural or historical significance.

Selected contacts were attributed with feature height and comments, and exported with an appropriately sized image in .tif format (typically 40m x 40m). Imagery was check-scanned by the sheet manager or mentor to ensure that no contacts were missed.

Side scan sonar coverage is determined by using mosaics generated in Caris HIPS and SIPS 5.4 and imported into MapInfo. If any deficiencies in the side scan sonar data were found, a holiday line file is created from the mosaics, and additional lines of SSS are acquired, in order to meet the requirements set forth in the Hydrographic Surveys Letter Instructions.

SSS contacts were inserted into Pydro for correlation and final resolution. Pydro automatically correlates the SSS contacts with the closest DP or Bathy feature that falls within correlation radius (non-AWOIS) with is set by the user in the Pydro PSS Parameters. Once the hydrographer was satisfied that the SSS contact has adequately been investigated, the contact is marked as **resolved-secondary-not charted** while the correlating primary feature (from bathymetry or DP) is marked **resolved-primary-chart**. Only the primary-chart items from Pydro are selected from Pydro for export to MapInfo for plotting on the final Feature Plot.

Feature Data

Prior to shoreline acquisition, a composite shoreline reference document is prepared by the Sheet Manager in the Mapinfo environment. This reference document contains the source shoreline provided with the project instructions. In addition to this source material, charted and/or non-source features that are not covered by source shoreline are color coded and added to the shoreline reference document for field verification. The composite shoreline reference document features are converted to Hypack-compatible formats (typically, .dxf for lines, and .dig for points) for display on the survey vessel, and printed for reference and note-taking.

Shoreline acquisition occurs during daylight periods near MLLW. A line is run along the shore as close as is safely navigable by a survey launch. While the line run does not determine the location of the inshore limit or contour of hydrography; it does do the following things:

- It gives a general idea of how close to shore mainscheme survey lines may be run.
- It allows the opportunity to verify the accuracy of all shoreline sources, including the chart and remote sensing data (DCFF, lidar, etc.).
- It allows field teams to visually search and locate significant features at MLLW.

As this line is run along the shore, the hydrographer is both annotating the shoreline reference document and looking for new **“**Navigationally Significant” features. All point features seaward of the limit contour should be verified with a DP or disproved. **“**Navigationally Significant**”** features are defined as the following:

- All features within the limits of safe hydrography.
- Features inshore of the limits of safe hydrography 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.
- Features inshore of the limits of safe hydrography which significantly (at the resolution requirement established for the survey) deflect this limit. Common examples of these features include foul areas and large reef/ledge structures.
- All man-made permanent features connected to the natural shoreline (such piers and other mooring facilities) that are sized to be chartable at current or planned next chart edition.. Seasonal features will be evaluated by the Chief of Party.
- All 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 be considered navigationally significant. Areas with a high density of mooring buoys for these vessels should be delineated, but the features themselves are not individually positioned.

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

“Noted”
- The existence of a feature and its characteristics are confirmed from a distance, and its position appears to be correct within the scale of the chart or source.
- Appropriate for features inshore of the limit of hydrography and not navigationally significant, or are unsafe to approach to verify position within survey scale.

“ Verified "
- The feature’s position and characteristics have been acquired and recorded either by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning will generally be by DGPS methods.
- Appropriate for new items within the limits of hydrography, or navigationally significant features inshore of this limit. Also appropriate for existing features with a source position not accurate at survey scale.

“Not Seen”
- The feature is 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 is 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. DPs were captured in the field as quick mark targets in HYPACK, with additional edits to the targets (range, bearing, depth and notes) added. Concurrent with the acquisition of these DP’s, digital photographs were taken of most features 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.

Following acquisition, target files (TGT) were edited when applicable to correct magnetic bearings for local variance so that all bearing were relative to true north. Additionally, DP names were changed to the format *vvvv_ddd_nnn* where *vvvv* is the vessel's hull number, *ddd* is the day of year and *nnn* is the position number (Ex: DP **1101_099_118** is the 118th position taken by vessel 1101 on day number 099). Finally the TGT files were saved with naming convention DP_*vvvv_ddd*.tgt for DPs and BS_*vvvv_ddd*.tgt for bottom samples.

A vessel configuration representing the majority of the targets was selected and TGT files were converted to HDCS format data using Pydro. Digital photos were renamed to match their respective DP's fix number and moved into a single folder. Final DP attribution, correction of vessel configurations, and linkage to digital photos were the preformed using Pydro. Any required application of tide and SV corrections were performed in CARIS HIPS.

S-57 Attribution

Hydrographic data become Pydro features in one of three methods:

- DPs which need to retain depth information, such as rocks and reefs, are converted to HDCS format data using Pydro. At the this point both tides and sound velocity may be applied in CARIS to produce corrected depths.
- DPs which require no depth information, such as bottom samples, are converted directly into the Pydro Preliminary Smooth Sheet (PSS) as GPs and retain only their position and attribution.
- Soundings which have been flagged as "designated" on cultural features such as wrecks or piles.

All Pydro XML features marked as "primary" were edited to have their object/attribute instances describe each feature as completely as possible. In some cases this required that multiple object classes be assigned to a single feature. Object attributes assigned to each feature conform to direction located within both the draft "S57 PYDRO guide" and the CARIS "IHO S-57/ENC Object and Attribute Catalogue".

The Pydro S-57 editor also has carto action flags which are edited to reflect the hydrographer recommendations as follows:

- **ADD --** A new feature was identified during survey operations. The hydrographer recommends adding the feature to the chart.
- **MODIFY --** The feature was found to be positioned or portrayed incorrectly on the chart. Modify 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.
- **DELETE --** The feature was disproved using approved search methods and guidelines. The hydrographer recommends removing it from the chart.
- **NONE --** (aka Retain) The feature was found during survey operations to be positioned correctly or was not investigated. The hydrographer recommends retaining the feature as charted.

Features selected for plotting on the DP and Bottom Sample Plot were flagged "Chart" in Pydro.

Pydro Depth and Feature Extraction

The final, combined BASE surface is inserted into Pydro by selecting **Data > Insert > HIPS**

BASE/Weighted grids. The PSS parameters **Localized Bathy-Grid Least Depth Size**, **Localized Bathy-Grid Surrounding Depth Size**, and **Localized Bathy-Grid Resolution** were left on their default values (15, 35, and 5 respectively). The resultant data is then excessed in Pydro using a 3-millimeter character size, ensuring that the largest spacing between selected soundings would not exceed 5 millimeters at survey scale. The final PSS was imported into Mapinfo using the "Draw PSS" function of Hydro_MI. Soundings were plotted in a 2-millimeter character size for data review. Data processing flow diagrams are included in Appendix I of this report.

Pydro Processing & Reports

Pydro was used to manage, attribute, and report features as described in Section 4.4 of the OCS Field Procedures Manual. All features were categorized, correlated, investigated as necessary, and resolved. Pydro was used to generate the Feature Report, Danger to Navigation Reports, and Requests for Approved Water Levels included with each survey.

CARIS Notebook

Project OPR-N161-RA-05 was the first entire project to produce CARIS Notebook HOB files as the shoreline deliverable. These CARIS Notebook HOB files replace the MapInfo shoreline plot, and feed directly into the H-Cell compilation process at the Pacific Hydrographic Branch.

In preparation for shoreline verification, all source data was imported into Notebook and saved as .hob files. This was accomplished by importing the provided CFF data into a project-wide file, and then subdividing by survey sheet. This survey-specific CFF file was named HXXXXX_CFF_Shoreline.hob. The survey manager also compared the CFF to the current chart in Mapinfo, digitizing any charted features not found in the CFF. This file of chart features was exported from Mapinfo as a .shp file and imported into Notebook using the Object Import Utility, and saved as HXXXXX_CHD_Shoreline.hob.

Prior to import into Notebook, detached positions (DPs) and generic positions (GPs) were processed through TGT_Editor.xls, and Pydro as described above. In addition to data analysis, standard flagging and S57 attribution, each feature received a CartoFlag of Add, Modify, Delete, or None. These features were then imported into Notebook using the software's Pydro Data Import function, which automatically creates ADD_PYDRO, MODIFY_PYDRO, DELETE_PYDRO, and NONE_PYDRO HOB files according to this flagging.

Currently there is no method to synchronize edits made to features in Notebook to the same features in PYDRO, or vice-versa. This issue is exacerbated by the fact that re-export of an .XML from PYDRO and import into Notebook overwrites all features and attribution of the original file in Notebook (not just the updated features). This re-export step must be performed after application of final approved water levels. For this reason all edits to features must be made in PYDRO prior to the import into Notebook. As a result, the separate ADD_Ntbk, MODIFY_ Ntbk, and a DELETE_ Ntbk are required to avoid overwriting non-Pydro features when updating Pydro features with final water levels or other data.

Edits on features not processed through Pydro are entered in one of several individual HOB files, according to data type:

- <u>"Noted"</u>: Items marked "noted" on the boat sheet were attributed as such in Notebook the CHD_Shoreline.hob or CFF_Shoreline.hob files, using the "REMRKS" attribute.
- <u>New Features Not Processed in Pydro</u>: Features without DPs or GPs which were digitized directly in Notebook were placed in the ADD_Notebook.hob file. Typical items would be new ledge or foul area limits digitized using the VBES buffer line as a guide.
- <u>Modified Features Not Processed in Pydro</u>: Features with attributes or positions modified based on field notes, but without a DP or other data processed in Pydro were changed as needed, and moved to the

MODIFY_Notebook.hob file.

- Deleted Features Not Processed in Pydro: Features disproved without a DP were moved to the DELETE_Notebook.hob file.

.HOB Deliverables	Description	File Source
HXXXXX_CFF_Shoreline.hob	Original RSD source with added notes from the hydrographer	Created by sheet OIC's. Clip excess data from Project Wide Source .hob files outside sheet limits.
HXXXXX_Charted_Shoreline.hob	Charted source from MapInfo with added notes from the hydrographer	Digitized in MapInfo – exported from MapInfo and imported using OIU scripts in to Notebook
HXXXXX_ADD_Ntbk.hob	New features digitized in Notebook	Hydrographer creates edit layer in Notebook
HXXXXX_MODIFY_Ntbk.hob	Modified features from the CFF and charted source	Hydrographer creates edit layer in Notebook
HXXXXX_DELETE_Ntbk.hob	Deleted features from the CFF and charted source	Hydrographer creates edit layer in Notebook
HXXXXX_ADD_Pydro.hob	New DP'd features exported from PYDRO and imported in to Notebook	Created during import from PYDRO
HXXXXX_MODIFY_Pydro.hob	Modified DP'd features exported from PYDRO and imported in to Notebook	Created during import from PYDRO
HXXXXX_DELETE_Pydro.hob	Deleted DP'd features exported from PYDRO and imported in to Notebook	Created during import from PYDRO
HXXXXX_NONE_Pydro.hob	Original RSD source with added notes from the hydrographer	Created during import from PYDRO

C. CORRECTIONS TO ECHO SOUNDINGS

Sound Velocity

Sound velocity profiles 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). Raw conductivity, temperature, and pressure data were processed using the program VelocWin version 8.72 which generated sound velocity profiles for CARIS in the .SVP format. VelocWin was also used to generate sound velocity profiles for Elac acquisition in the .*SVA* format. Calibration reports and dates of the SeaCat profilers are included in the NOAA Ship RAINIER 2005 Field Season Hydrographic Systems Certification Report.

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 1016 and 1015.

The Reson 8125 SWMB system utilized on vessel 1016 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 Elac 1180 SWMB system utilized on vessels 1016 and 1015 is a beam-steered flat-faced transducer system which produces the best results when SV correctors are applied to both the transducer-water interface and the water column itself. To correct SV at the face of the transducer, a real time SV value is feed directly into the HydroStar acquisition software from an Odom Digibar Pro, model db1200 velocimeter. To correct beam-steering in the water column, the *.SVA* file produced by VelocWin is also input into the HydroStar acquisition software and is used until replaced with another *.SVA* file.

Occasionally circumstances would dictate taking an SV cast after the acquisition of SWMB data to which the cast was intended to be applied. In this event the cast was manually backdated so that it would be applied to the SWMB data correctly. Sound velocity profiles for CARIS were concatenated by vessel in order of ascending time/date and saved in the same directory as the individual SVP files for each vessel. A naming convention of H*xxxxx*_*vvvv*_SVP.SVP was used where H*xxxxx* is the sheet's registry number and *vvvv* is the vessel's hull number (Ex: **H11292_1006_SVP.SVP** is the concatenated SVP file for hull number 1006 for sheet H11292). This concatenated file was then applied to all HDCS data collected by that particular vessel with the option **Previous in time** 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 2005 RAINIER System Certification Report.

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	February 2005	Surface analysis	April 2005	Sequim Bay, WA
1103	February 2005	Surface analysis	April 2005	Sequim Bay, WA
1021	February 2005	Surface analysis	April 2005	Wrangell Narrows, AK
1016	February 2005	Surface analysis	March 2005	Lake Washington, WA
1006	February 2005	Surface analysis	March 2005	Lake Washington, WA
1015	February 2005	Surface analysis	April 2005	Sequim Bay, WA

Settlement and squat observations were conducted for all launches using a surface analysis method. An area of flat topography was selected in a protected area to minimize any heave or chop. When possible observations were conducted in a lake to negate any tidal influence. A line was then run repeatedly in the same direction at different speeds while logging data. Finally data was collected at three pre-selected target areas on the same line while the launch was at rest. Settlement and squat speed curves were derived by querying these target areas using CARIS and graphing the change of apparent depth at different speeds.

Vessel offsets and static draft were measured using both steel tapes and a LEICA laser distance meter. 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 used to collect SWMB data each have a separate HVF associated with each individual acquisition system aboard. Each of these HVFs contain sensor offset and dynamic draft correctors that pertain to this single acquisition system. Sensor offset and dynamic draft correctors were applied to SWMB data in CARIS during post-processing. Vessel offset diagrams and dynamic draft tables are included in included in the NOAA Ship RAINIER 2005 Field Season Hydrographic Systems Certification Report. 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
1006_Reson8101_HVF	Jensen hull 1106, SWMB using hull mounted Reson 8101
1015_Elac1180_HVF	Jensen hull 1015, SWMB using hull mounted Elac 1180
1015_K5K_100_HVF	Jensen hull 1015, 100% SSS using hull mounted Klein 5000
1015_K5K_200_HVF	Jensen hull 1015, 200% SSS using hull mounted Klein 5000
1016_Reson8125_hvf	Jensen hull 1016, SWMB using hull mounted Reson 8125
1021_reson8101_HVF	Jensen hull 1021, SWMB using swing-arm mounted Reson 8101
1101_Echosounder_DP	Jensen hull 1101, detached positions using echosounder
1101_NonEchosounder_DP	Jensen hull 1101, detached positions not using echosounder
1101_Singlebeam_HVF	Jensen hull 1101, singlebeam using Knudsen 320M
1101_TowedSSS_HVF	Jensen hull 1101, SSS using towed Klein 3000
1103_Echosounder_DP	Jensen hull 1103, detached positions using echosounder
1103_NonEchosounder_DP	Jensen hull 1103, detached positions not using echosounder
1103_Singlebeam_HVF	Jensen hull 1103, singlebeam using Knudsen 320M
dive	Dive investigation (depth determined using a diver least-depth gauge)

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 Reson-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.

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in the 2005 RAINIER System Certification Report.

All SWMB 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. All applicable HVFs are included with the digital HDCS data.

Water Level Correctors

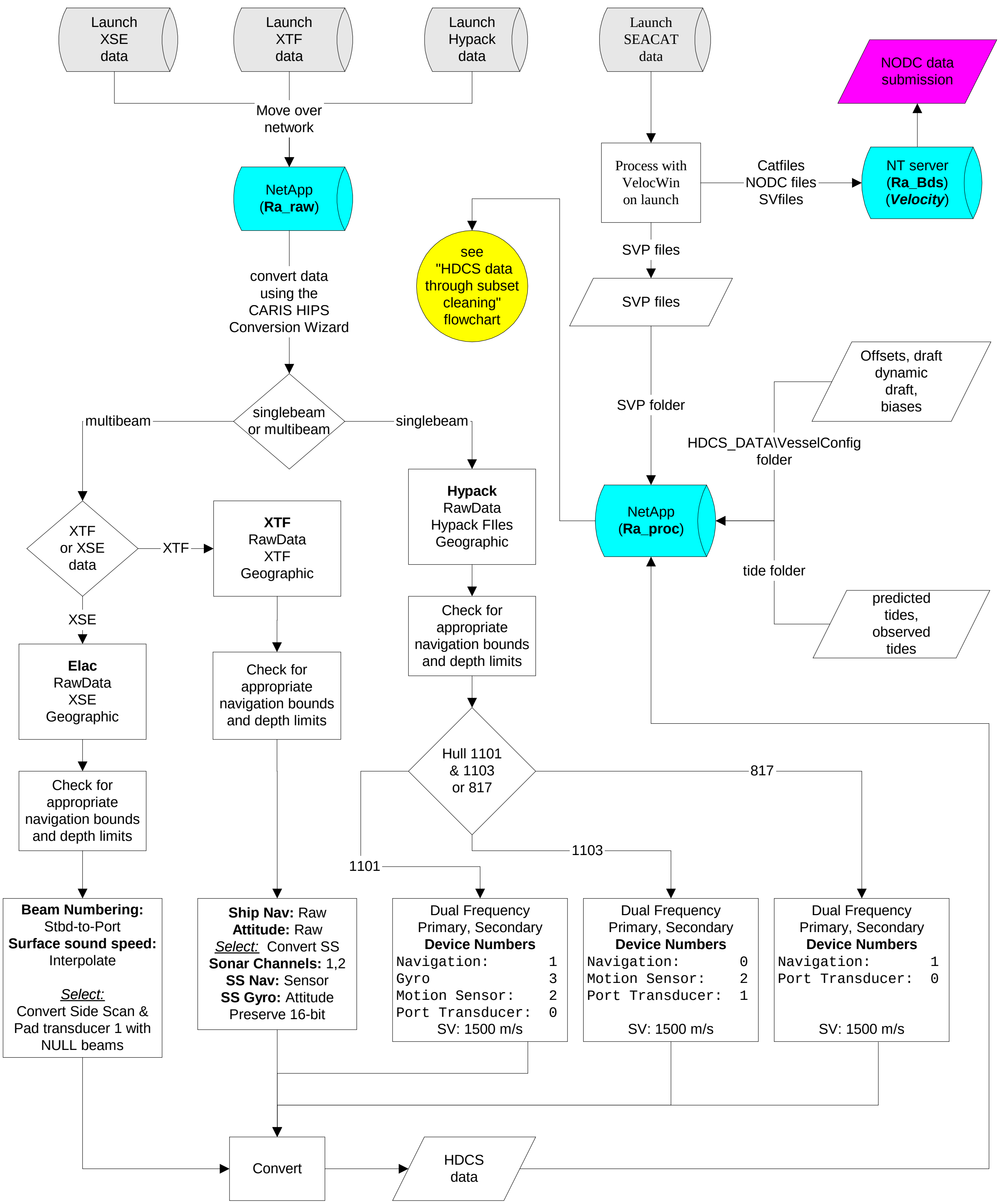
Soundings were reduced to Mean Lower-Low Water (MLLW) using final approved water levels from stations Cherry Point, WA (944-9424) and Friday Harbor, WA (944-9880) using the tide files 9449424.tid and 9449880.tid. The final approved water level data from these two reference stations were applied to the survey depths in CARIS using height ratio and time correctors from the CO-OPS provided zone definition file N161RA2005CORP.zdf.

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.

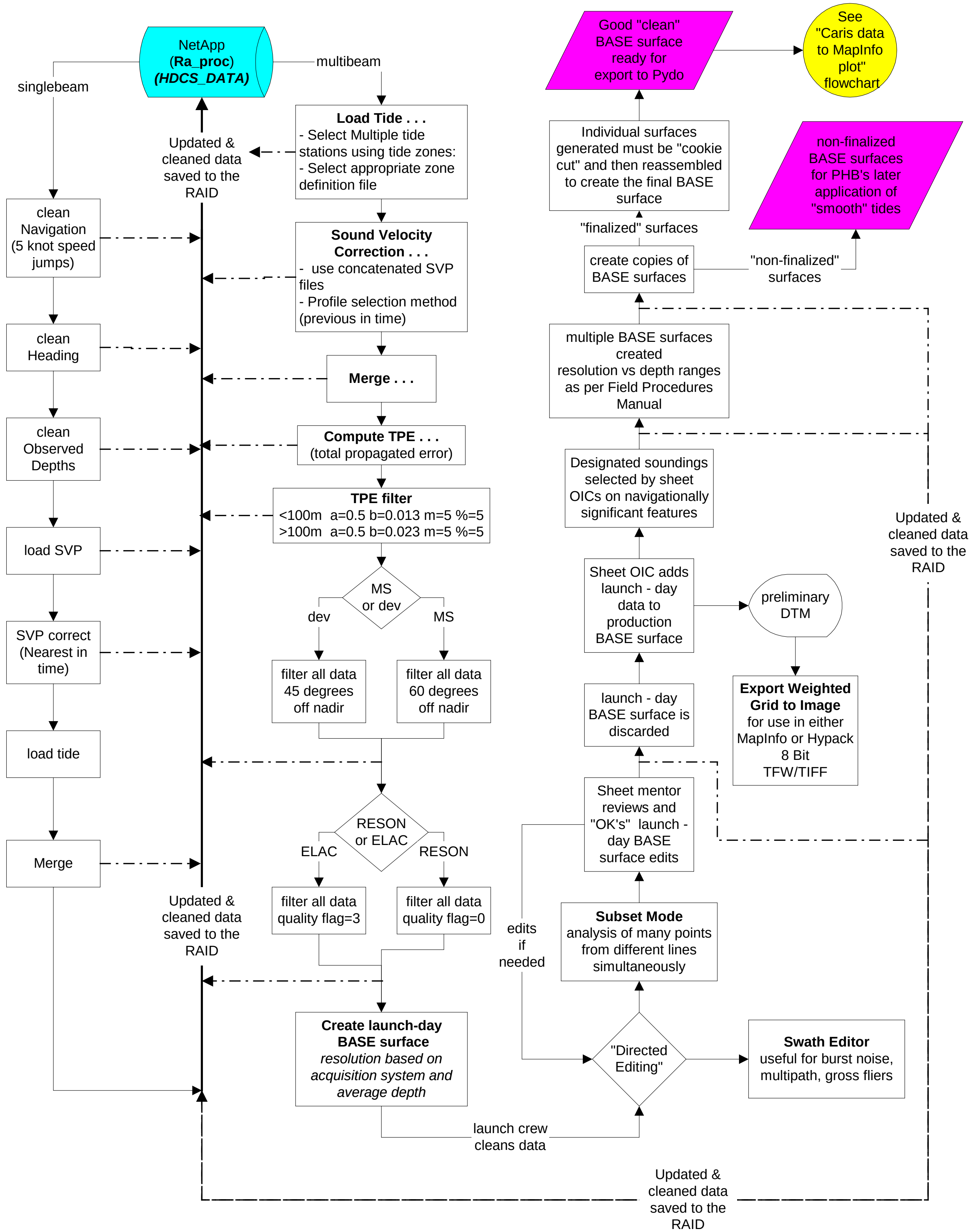
APPENDIX I

Data Processing Flow Diagrams

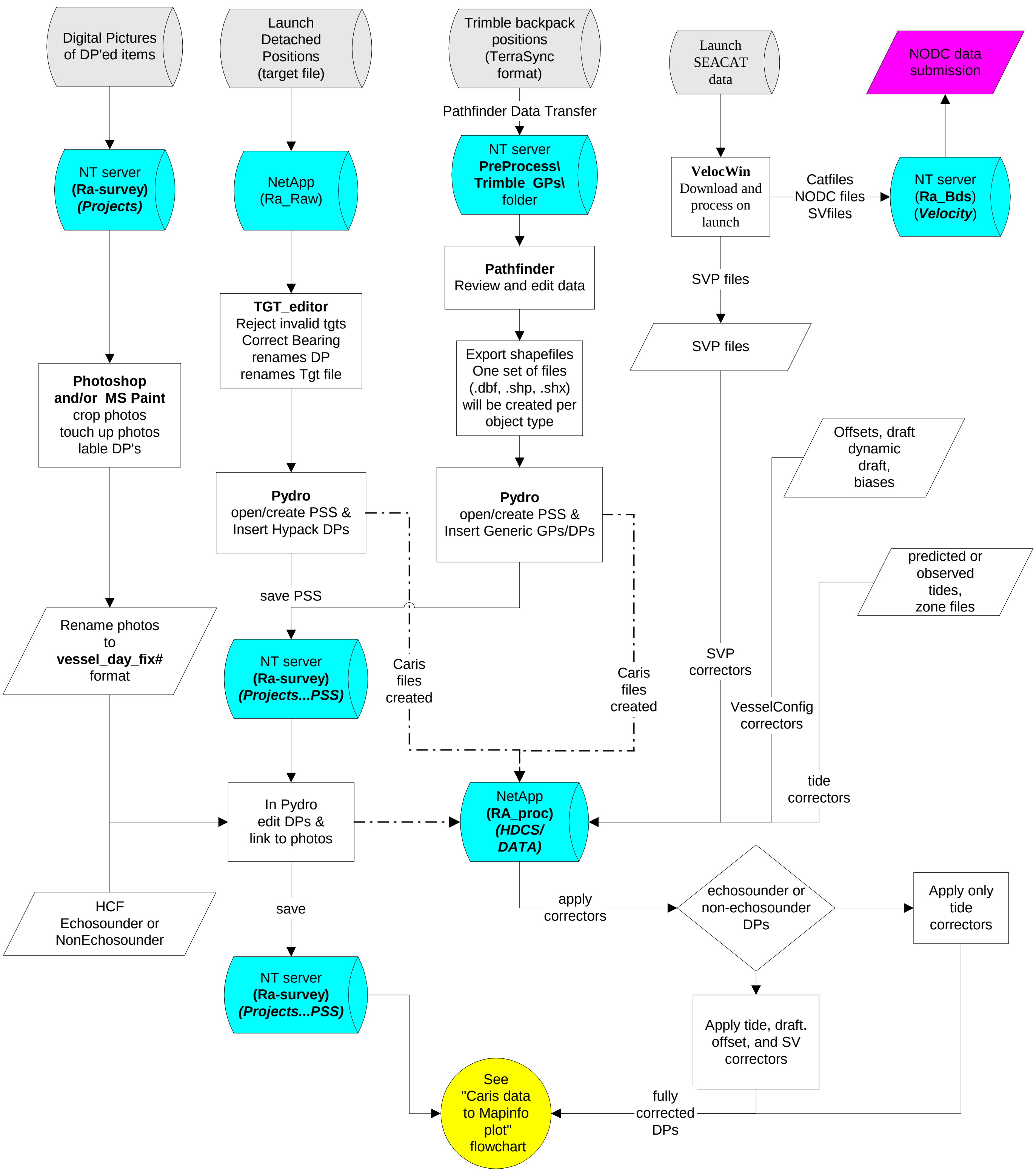
Raw sounding data to HDCS



HDCS data through subset cleaning



Detached Position processing (Raw DP's to Pydro)



Detached Position processing in Pydro