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NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey Hydrographic
Project No. OPR-N161-RA-06
Time frame September - November 2006

LOCALITY

State Washington
General Locality Approaches to Anacortes and Bellingham

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2006
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CHIEF OF PARTY

..... Commander Guy T. Noll, NOAA

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DATE

Data Acquisition and Processing Report

NOAA Ship RAINIER (s221)

OPR-N161-RA-06

Approaches to Anacortes and Bellingham, Washington
Hydrographic Letter Instructions dated August 15, 2006
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:

<u>Hull Number</u>	<u>Vessel type</u>
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
S221	231 foot steel hydrographic ship

Vessels 1021, 1016, 1006, 1015 and S221 are used to acquire shallow-water multi-beam (SWMB) data and sound velocity profiles. Vessel 1103 is used to collect vertical-beam echosounder (VBES) data and detached positions. Vessel 1015 is 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 2006 NOAA Ship RAINIER Hydrographic Readiness Review Package.

Six different categories of echosounder systems were utilized for project OPR-N161-RA-06. 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 *2006 NOAA Ship RAINIER Hydrographic Readiness Review Package*.

Sounding Equipment:

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

Vessels 1021 and 1005 are equipped with Reson SeaBat 8101 multibeam echosounders. The SeaBat 8101 is a 240 kHz multi-beam system that measures relative water depths across a 150° swath, consisting of 101 individual 1.5° x 1.5° 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. Both echosounders have 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 1006 is configured with the 8101 transducer mounted permanently in a cut-out section of the vessel’s keel.

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° swath, consisting of 240 individual 0.5° x 1.0° 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 and Intermediate-Depth Multi-beam

Vessel 1015 is 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° wide with a spacing of 1.25°, for a total of 9 beams per sector. There are 7 fanwidth settings possible, the maximum of which (153.5°) 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 131° (116 beams) or 108° (90 beams), depending on water depth, sea state, data quality, and coverage requirements. When operated concurrently with the Klein 5500 side scan sonar, the system is operated in 86° (72 beams) mode to avoid acoustic interference. 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. ELAC 1050D MKII Shallow and Intermediate-Depth Multibeam

S221 (RAINIER) is equipped with a hull-mounted SeaBeam/Elac (Elac) 1050D MKII, which is a dual frequency (180 kHz, 50 kHz), high-resolution multibeam echo sounder system for shallow- and intermediate-water depths. Each frequency uses two flat-faced transducers, one starboard and one port, for a total of four transducers in the transducer housing. Each set of transducers, starboard and port, are mounted at a 38° angle from horizontal. During data acquisition only one frequency at a time is active. 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° wide with a spacing of 1.25° , for a total of 9 beams per sector. There are 7 fanwidth settings possible, the maximum of which (153.5°) utilizes 7 sectors, for a maximum total of 126 beams within a “virtual swath.” RAINIER personnel typically operate the Elac 1050D on a swath width of 131° (116 beams) or 108° (90 beams), depending on water depth, sea state, data quality, and coverage requirements. The Elac 1050D was operated exclusively on 50 kHz for this project, as shipboard testing has shown this frequency to produce less noisy, more accurate soundings than the 180 kHz band in water depths greater than 100m.

Because the RDT beam forming method described above requires three ping cycles to fully ensonify the coverage swath, the Elac 1050D 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 1050D is not utilized to obtain full bottom coverage in water depths less than 100 m.

5. Launch Vertical Beam Echosounder (VBES)

Vessel 1103 is 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 some offshore reefs and shoals which were inaccessible to MBES-equipped boats, in depths generally ranging from 0 to 20 meters. VBES 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. 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 2006. Calibration reports are included in the *2006 NOAA Ship RAINIER Hydrographic Readiness Review Package*.

| **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 1015 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 Elac 1180 MBES installed on Vessel 1015 is typically operated in 86° mode while operating the Klein SSS to provide a “skunk stripe” of bathymetry in the center of the SSS swath.

2. Multibeam Echosounder Backscatter

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 1015 and S221 also provides a very low-resolution digital SSS record of the multi-beam swath. 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. 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:

1. Trimble DSM-212L

Vessel 1103 is 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

2. Applanix POS MV 320

Vessels 1021 and 1015 are equipped with TSS POS/MV 320 (version 3) while vessels S221, 1016 and 1006 are equipped with TSS POS/MV 320 (version 4) Position and Orientation Sensors to measure and calculate position. The POS/MV is a GPS-aided inertial navigation system, which provides a blended position solution derived from both an Inertial Motion Unit (IMU) and an integrated GPS receiver. The IMU and GPS receiver are complementary sensors, and data from one are used to filter and constrain errors from the other. This inter-dependence results in higher position accuracy and fewer errors than either system could

produce by itself. Position accuracy is displayed in real time by the POS/MV software and was monitored to ensure that positioning accuracy requirements as outlined in the NOS Hydrographic Surveys Specifications and Deliverables were not exceeded. In addition, the POS/MV software displays HDOP and 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. TSS MAHRS

Vessel 1103 is equipped with a TSS MAHRS Surface Product (**M**eridian **A**ttitude and **H**eading **R**eference **S**ystem). Using an orthogonal array of three linear accelerometers and three angular rate systems, the MAHRS computes heave, pitch and roll values. The MAHRS has an internal gyroscope which applies dynamic tuning and the effects of gravity and earth rotation to provide a true north reference. Due to the physical properties of a north-seeking gyrocompass, accuracy is dependant upon the operation latitude and the vessel dynamics. To optimize performance, the MAHRS uses information input from the launches's Trimble GPS to apply both latitude and vessel speed correctors. The MAHRS has a dynamic heading accuracy less than $\pm 0.1^\circ$ and a static error less than $\pm 0.5^\circ$. The roll and pitch resolution is 0.1° with an accuracy of 0.03° at less than 5° of roll and 0.5° for greater than 5° of roll. The heave resolution is one centimeter, with an accuracy of 5 centimeters or 5% of the range, whichever is the greater.

2. Applanix POS MV

RAINIER and her SWMB launches (Vessels S221, 1021, 1016, 1006 and 1015) are equipped with TSS POS/MV Model 320 Position and Orientation System – Marine Vessel (POS/MV) sensors, which provide accurate navigation and attitude data to correct for the effects of heave, pitch, roll and heading. The POS generates attitude data in three axes (roll, pitch and heading) to an accuracy of 0.05° or better. Heave measurements supplied by the POS/MV maintain an accuracy of 5% of the measured vertical displacement for movements that have a period of up to 20 seconds. The Heave Bandwidth filter was configured with a damping coefficient of 0.707. The cutoff period of the high pass filter was determined by estimating the swell period encountered on the survey grounds. These values ranged from 8 s (flat water) to 20 s (long period ocean swell), with values of 8 or 12 s typical.

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. At this time, TrueHeave cannot be applied to Elac bathymetry because the Elac systems cannot be accurately time synchronized to the POS MV. See Section C. below for additional information.

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-Elies' ISIS software and logged in the Extended Triton Format (XTF). Reson bathymetry was logged in the XTF file in “0x18 RI_Theta” format.

Rainier and 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.

All SWMB data were processed using the CARIS Hydrographic Information Processing System (HIPS) and Hydrographic Data Cleaning System (HDCS) software version 6.0 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 6.0 for the Microsoft Windows environment.

All VBES data were acquired using Coastal Oceanographic's HYPACK MAX in the "RAW" format. VBES data were processed using CARIS HIPS 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 *2006 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 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 guidance¹, 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

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.

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.

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 and Elac 1050D MKII. 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 CUBE (Combined Uncertainty and Bathymetry Estimator) surface as implemented in HIPS version 6.0. 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 soundings 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 (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.

Any individual soundings 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. The tidal value zoning is given in the Letter Instructions 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 is always 0.5 m/s, the error for the SeaBird 19plus. Sound speed value surface for flat face transducers like the Reson 8125 and the Elac 1180 on 1016 and 1015 is 0.3 m/s, the error of the Digibar Pro. All other launches that have no sound speed correctors and the transducer face use a value of 0.0 m/s. All other error estimates are read from the Hydrographic Vessel File (HVF) and Device Model file.

The exact behavior of CUBE is determined by the values set in the CUBE Parameters File (CUBEParams.xml). RAINIER uses parameters which have been tuned by Hydrographic Systems and Technology Programs (HSTP) personnel to optimize performance of the CUBE algorithm in typical Alaskan bathymetry. This modified file is stored in the central CARIS VesselConfig directory, and is submitted with each survey.

Vessel	Tide values measured	Tide values zoning	Sound speed values measured	Sound speed values surface
1006 Reson8101 HVF	0.01	0.07	0.50	0.00
1015 Elac1180 HVF	0.01	0.07	0.50	0.30
1015 Elac1180 HVF ExtendedDraft	0.01	0.07	0.50	0.30
1016 Reson8125 hvf	0.01	0.07	0.50	0.30
1021 reson8101 HVF	0.01	0.07	0.50	0.00
1103 Singlebeam HVF	0.01	0.07	0.50	0.00
S221 Elac1050D LF	0.01	0.07	0.50	0.00

Table #1 (TPE Values for Tide and Sound Velocity)

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 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.
2. Load predicted tides.

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.

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 with poor quality flags, (0 for Reson and 3 for Elac).
 - b. Reject soundings with TPE greater than the horizontal and vertical error limits specified in the NOS Hydrographic Surveys Specifications and Deliverables:

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

$$\text{Vertical Error} > \pm\sqrt{a^2 + (b * d)^2}, \text{ where “a” and “b” are defined as}$$

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 CUBE surface in the “Hxxxxx_Processing” field sheet.

The naming convention for these “temporary” CUBE surfaces is “Launch Number_DnXXX” (Example: “1006_Dn095”). Typically these daily CUBE surfaces are created with resolutions between 2 and 10 meters. When selecting the boat-day CUBE 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.

The following options were 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).

Preliminary, daily data cleaning is performed using the Boat-Day CUBE 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 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, it has become possible to adjust the CUBE 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.

After initial cleaning is complete, the Boat-Day CUBE Surface is reviewed by the Survey manager and Mentor. At no point does the launch crew re-compute the Boat-Day CUBE surface which could result in obscuring mistakenly rejected features behind a now "smooth" CUBE 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 CUBE Surface. The Manager is responsible for accepting the data and adding it to the appropriate production CUBE surface in the "HXXXXX" Field Sheet. Specific data quality factors are discussed in the Descriptive Report for each survey.

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

As the last step to finalize survey data, multiple CUBE 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, RAINIER 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 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 the Field Procedures Manual will be noted in that survey's Descriptive Report.

Unfortunately, at the time this document was generated, the multiple resolution option for creating a CUBE surface was not properly working. 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. This step can occur only after navigationally significant cultural features such as piles and wrecks have been flagged as "designated" so that the CUBE 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 CUBE surface. This dual submission is required since CARIS does not allow tides to be applied to CUBE surfaces that have already been finalized and thus PHB would not be able to apply final approved water levels.

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 & ½ m 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 and depth ranges specified in the Field Procedures Manual Version 2.1 (see table 1). 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.

Depth Range Filtering	Final CUBE 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 2 Depth range vs. CUBE surface resolution

These 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.

Vertical Beam Echosounder Data

Vertical Beam Echosounder 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 CUBE 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 CUBE 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.

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 5500 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
- 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 6.0 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. Under typical circumstances, once the hydrographer is 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.

Due to the large number of SSS contacts selected throughout the project area, the decision was made to avoid picking a designated sounding to correlate with each individual SSS contact. To this end, all SSS contacts were divided into one of three individual categories for categorization and annotation:

- In the event of a large isolated feature discovered by SSS that merits a distinct cartographic treatment on the smooth sheet or chart, the least depth is designated as per the standard procedure. The designated sounding is brought into Pydro via import feature and designated **primary** and the SSS contact is designated **secondary**. The report flag is checked and a clear charting recommendation is made in the appropriate tab.
- In an area covered with 100% SWMB and littered with SSS contacts that do not merit individual cartographic treatment, a "rocky area" designation is used. In such a "rocky area" the BASE surface is checked to ensure that it adequately captures the least depths of all rocks. SSS contacts in the "rocky area" are consolidated in Pydro using the "group" tool to force correlation of all the SSS features which would have otherwise been outside the correlation radius. Once this is done the SSS contact nearest the center of the rock cluster is classified primary and all the other contacts secondary. The primary contact is annotated to include the investigation technique and results in the remarks. Charting recommendations (typically, "Chart soundings only, add annotation "Rky" to

chart at approximate position <lat>, <lon>") are made in the recommendations tab. S-57 classification is SBDARE, and "add". Flagging should be Significant, Chart, Report, and Resolved.

- In the case of scattered contacts that have been developed with individual lines it is usually possible to simply look at the MBES coverage in subset mode or the Pydro bathy grid. If the contact is determined to be insignificant (>1m in height in ≥ 20 m of water, height >10% of water depth in >20m of water), the Primary SSS contact is annotated accordingly and no sounding is designated. Isolated SSS contacts which are confirmed to meet significance criteria shall have designated soundings as per the standard procedure.

Feature Data

Prior to shoreline verification operations, a composite shoreline reference document is prepared by the Survey Manager in the CARIS Notebook 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, 000 formatted S-57 file) for display on the survey vessel, and printed for reference and note-taking.

Shoreline verification occurs during daylight periods near MLLW. A line is run along the shore approximating the position of the Navigational Area Limit Line (NALL). In the absence of direction to the contrary, the NALL shall be the furthest offshore of the following:

- The 4m depth contour at MLLW.
- A line seaward of the MHW line by the ground distance equivalent to 0.8mm at the scale of the largest scale raster chart of the area.

This definition of the NALL is subject to modification by the Letter Instructions, Chief of Party (Commanding Officer), or (in rare instances) Hydrographer-In-Charge of the survey launch. Some possible reasons for modifying this direction include:

- Sea conditions in which it is unsafe to approach shore to the specified distance or depth.
- Regular use of waters inshore of this limit by vessels navigating with NOAA nautical chart products. (*This does **not** include skiffs or other very small craft navigating with local knowledge.*)

As the approximate NALL line is run along the shore, the hydrographer both annotates the shoreline reference document and scans the area for features which must be addressed. Feature types to be addressed are as follows:

- Seaward of the NALL:
 - New features not in the Composite Source file.
 - Features from NGS Source (DCFF, LIDAR).
 - AWOIS items and other features specifically identified for investigation.
- Inshore of the NALL:
 - Navigationally significant features only, as defined below.

Navigationally Significant" features are defined as the following:

- All features within the limits of safe navigation (i.e., offshore of the NALL).
- Features inshore of the NALL which:
 - are sufficiently prominent to provide a visual aid to navigation (landmarks). Note that rocks awash are almost never landmarks, but distinctive islets or other features visible at MHW can be useful for visual navigation.

- significantly (a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area) deflect this limit. In Alaska, common examples of these features include foul areas and large reef/ledge structures.
- are man-made permanent features connected to the natural shoreline (such piers and other mooring facilities) larger than the resolution specified for the survey. Seasonal features will be evaluated by the Command.
- are man-made permanent features disconnected from the shoreline, such as stakes, pilings, and platforms, regardless of size.

Small, private mooring facilities (piers and buoys) suitable for pleasure craft will not generally be considered navigationally significant. Areas with a high density of mooring buoys for these vessels should be delineated, but the features themselves not individually positioned.

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

“Noted”

- The existence of a feature and its characteristics are confirmed from a distance, and its position appears to be correct within the scale of the chart or source.
- Appropriate for features inshore of the limit of hydrography and not navigationally significant, significant features that require no further investigation, or features unsafe to approach to verify position within survey scale.

“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.

“DP for Height”

- The feature’s source position is correct, but height (VALSOU or HEIGHT attribute) is either unknown or incorrect. **This position will not supersede that of the source data, so it is necessary only to approach the feature as closely as required to accurately estimate height. However, it is critical that these positions be correctly linked to the features they modify to avoid confusion during processing.**
- Appropriate for source features found within 20m of their source positions, but with incorrect or missing height or depth data.

“New”

- The feature’s position and attributes (including height) 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 items seaward of the NALL that are not present in the Composite Source.
- Items inshore of the NALL which are navigationally significant and are not present in source data.

“Not Seen”

- The feature is present in source data (chart, DCFE, 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

Pydro features may be created by many different 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.
- Lidar investigation features imported into Pydro for further evaluation.
- SSS contacts that have been selected in CARIS and imported into Pydro for correlation and further evaluation.

S-57 attribution is not required for those features flagged as "secondary". All Pydro XML features marked as “primary” are 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 transfer to Notebook were flagged “Chart” in Pydro.

Pydro Depth Extraction

The final, combined CUBE 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. 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

Source shoreline files are most often either Cartographic Feature Files (CFF) or Electronic Navigational Charts (ENC) that have been updated with the latest photogrammetric surveys. CFFs were received from the Remote Sensing Division (RSD) and converted to project wide HOB files by either the FOO or CST. Prior to sending the files to the field, RSD passed the CFF data through an S57 converter that separated it into S57 Object Class files based on the notes entered in the Attribute Field (e.g. “Natural.Mean High Water” becomes COALNE). These S57 classified CFF files were then provided to RAINIER as both MapInfo table files (.TAB) and as ESRI shape files (.SHP). The Object Import Utility embedded in Notebook then utilized series of OIU conversion scripts to import ESRI shape file features into Notebook as an attributed HOB file.

If available, ENC source (.000) files were also converted to project wide HOB files. ENC objects were culled down, retaining only the features to be verified in the field. A RAINIER created complex filter was utilized to remove these unnecessary S57 objects from the ENC file

In preparation for shoreline verification, the Survey Manager copied all project wide HOB files and cropped them to include only items contained on their assigned sheet. If no ENC source data was available, the survey manager also compared the HOB files to the current raster chart in Notebook. Any charted features not found in the HOB files were digitized as a charted source HOB file. All unedited source data HOB files were then compiled into new edit layer named HXXXXXX_Original_Comp_Source. Finally all these features from multiple shoreline feature sources were de-conflicted (see table#3) and saved in a HOB file named HXXXXXX_Deconflicted_Comp_Source.

Hierarchy	MLLW (Tide Corrected)	Point Features & Line Features (Not Tide-Corrected)
1	Prior Survey	CFF
2	LIDAR	LIDAR
3	ENC	Prior Survey
4	CFF	ENC

Table 3 Source data HOB file de-confliction hierarchy

The Survey Manager next creates a composite shoreline reference document, the paper representation of the shoreline that will be used to write observations in the field. The de-conflicted source layers are color coded so that the individual layers can easily be distinguished and sent directly to the plotter from Notebook. Digital HOB files were exported in a 000 formatted S-57 file which can be directly opened in Hypack.

For surveys where limited shoreline verification was performed, all field notes were placed in the remarks field of the applicable source HOB. Marker layers were created for notes not associated with S57 objects. DPs and/or Caris VBES/SWMB CUBE surfaces were used to help define kelp and foul areas. Line features in the applicable source HOB were modified and/or partially deleted. In the case of new line features, they were digitized in **HXXXXX_FieldVerified_Source.HOB**. In all cases, be it lidar or CFF, when objects were added or modified the SORDAT and SORIND fields were updated. As a final step, filters were used in the Pydro to XML step before the Notebook import to create both **HXXXXX_Pydro_Updates** and **HXXXXX_PYDRO_Disprovals**. In the case of non-lidar survey the Notebook HOB files to be submitted as your survey’s shoreline deliverable are:

- **HXXXXX_Original_Comp_Source** – A compilation of all shoreline source files, unedited.
- **HXXXXX_Deconflicted_Comp_Source** - A compilation of all shoreline source files after de-confliction where all unnecessary duplicate features have been removed.
- **HXXXXX_FieldVerified_Source** – Includes all new line features (kelp, foul limits, etc) and all features from the individual source layers (CFF_Source, ENC_Source, etc.) after verification, final edits, and attribution.
- **HXXXXX_Pydro_Updates** – All new or modified features from Pydro.
- **HXXXXX_Disprovals** – Features disproved in Pydro, with either a DP or GP.

Prior to import into Notebook, detached positions (DPs) and generic positions (GPs) were processed through TGT_Editor.xls, and/or Pydro as described above. Features were prepared for Notebook by passing them through filters prior to the XML export. These features were then imported into the appropriate Notebook HOB file using the software’s Pydro Data Import function.

The SORDAT and SORIND fields were filled in for any objects added to or modified in any HOB file. The VALSOU (also SORDAT and SORIND) attribute of all features DP’ed for height was entered using the Pydro height value corrected with for final tides.

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 final import into Notebook.

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 8.8 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 *2006 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 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 vessel 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.

The Elac 1050D MBES system installed on vessel S221 also features a beam-steered, flat-faced transducer. Real time sound speed measurements from the vicinity of the transducer head were measured by a Seabird SBE-45 thermosalinograph (TSG) permanently installed aboard the ship. At present, there is not automatic interface to connect the TSG output to the Elac hardware of software, so significant (+/-1m/s) deviations in surface sound speed were manually entered in the HydroStar .SVA file at the appropriate depth.

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 Hxxxxx_vvvv_SVP.SVP was used where Hxxxxx 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 *2006 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
1103	February 2005	Optical & Surface analysis	March 14, 2006	Lake Washington, WA
1021	February 2005	Optical & Surface analysis	March 27, 2006	Lake Washington, WA
1016	February 2005	Optical & Surface analysis	March 14, 2006	Lake Washington, WA
1006	February 2005	Optical & Surface analysis	April 6, 2006	Lake Washington, WA
1015	February 2005	Optical Level	March 27, 2006	Lake Washington, WA
S221	April 2003	OTF*	March 1999	Port Angeles, WA

*OTF: "On-the-fly" GPS techniques

Settlement and squat observations were conducted for all launches with the exception of 1015 using a surface analysis method. The procedure follows the one outlined in the FPM (1.4.2—Vessel Dynamic Offsets). In Lake Washington, an area of flat topography was selected in a protected area to minimize any heave or chop. Observations conducted in a lake also have the added benefit of negating any tidal influence. 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 CARIS and graphing the change of apparent depth at different speeds.

The optical level method was conducted for all launches. The procedure followed the one outlined in the FPM (1.4.2—Vessel Dynamic Offsets). One line drawn in Lake Washington was used to acquire the data. 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 same RPM's were used for both the optical level and surface analysis methods.

The 1015_Elac1180_HVF_ExtendedDraft HVF was created by manually extrapolating both the speed and draft correction from the original values obtained using the optical level method. This extrapolation was necessary due to hull 1015 exceeding 4.7 m/s, the highest speed measured using optical level method, while conduction simultaneous Elac and SSS data collection. This high speed resulted in a noticeable artifact in the DTM which was corrected with the extended HVF values. Additional information on this process is included in the Descriptive Reports of the affected surveys.

Vessel offset measurements for the survey launches were verified in 2006, however due to unclear documentation these values were not submitted with the 2006 Hydrographic Readiness Review Package. The 2005 offset values were considered adequate and were used during the 2006 field season. In 2005, 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 (HVF's). Survey platforms with more than one acquisition method have a separate HVF associated with each individual acquisition system aboard. Each of these HVF's contain sensor offset and dynamic draft correctors that pertain to this single acquisition system. Sensor offset and dynamic draft correctors were applied to bathymetric data in CARIS during post-processing. Vessel offset diagrams and dynamic draft tables are included in included in the 2006 NOAA Ship RAINIER Hydrographic Readiness Review Package. The HVF's 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 nonechosounder dp	Jensen hull 1006, detached positions not using echosounder
1006 Reson8101 HVF	Jensen hull 1006, SWMB using hull mounted Reson 8101
1015 Elac1180 HVF	Jensen hull 1015, SWMB using hull mounted Elac 1180
1015 Elac1180 HVF ExtendedDraft	Jensen hull 1015, SWMB using hull mounted Elac 1180 (for speed up to 7.0 m/s)
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
1103 NonEchosounder DP	Jensen hull 1103, detached positions not using echosounder
1103 Singlebeam HVF	Jensen hull 1103, singlebeam using Knudsen 320M
S221 Elac1050D LF	Ship hull S221, SWMB using hull mounted Elac 1050D MKII

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 was 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). After regular CARIS data conversion this TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw XTF data.

An offset between the time stamps of TrueHeave data and the XSE data as converted in CARIS prevented TrueHeave from being applied to any Elac data. Even though this TrueHeave data could not be used it was retained in the hope that CARIS might one day solve this time stamp problem. At the time of this writing no such time stamp fix exists.

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in the *2006 NOAA Ship RAINIER Hydrographic Readiness Review Package*.

All vessel offsets, dynamic draft correctors, and system bias values are contained in CARIS HIPS Vessel Files (HVF's) 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

Soundings were reduced to Mean Lower-Low Water (MLLW) using verified observed final approved water levels from stations at Friday Harbor, WA (944-9880) and Cherry Point, WA (944-9424) using the tide files 9449880.tid and 9449424.tid. The final approved water level data from this reference station was applied to the survey depths in CARIS using height ratio and time correctors from the CO-OPS provided zone definition files (HxxxxCORP.zdf) created specifically for each individual survey.

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 2006 edition), NOS Hydrographic Surveys Specifications and Deliverables (June 2006 edition), and all HSD Technical Directives issued through November 2006. All departures from these standard practices are described in this Data Acquisition and Processing Report and / or the relevant Descriptive Reports.

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

Approved and Forwarded:

Guy T. Noll
Commander, NOAA
Commanding Officer

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

Chief Survey Technician:

James B. Jacobson
Chief Survey Technician, NOAA Ship RAINIER

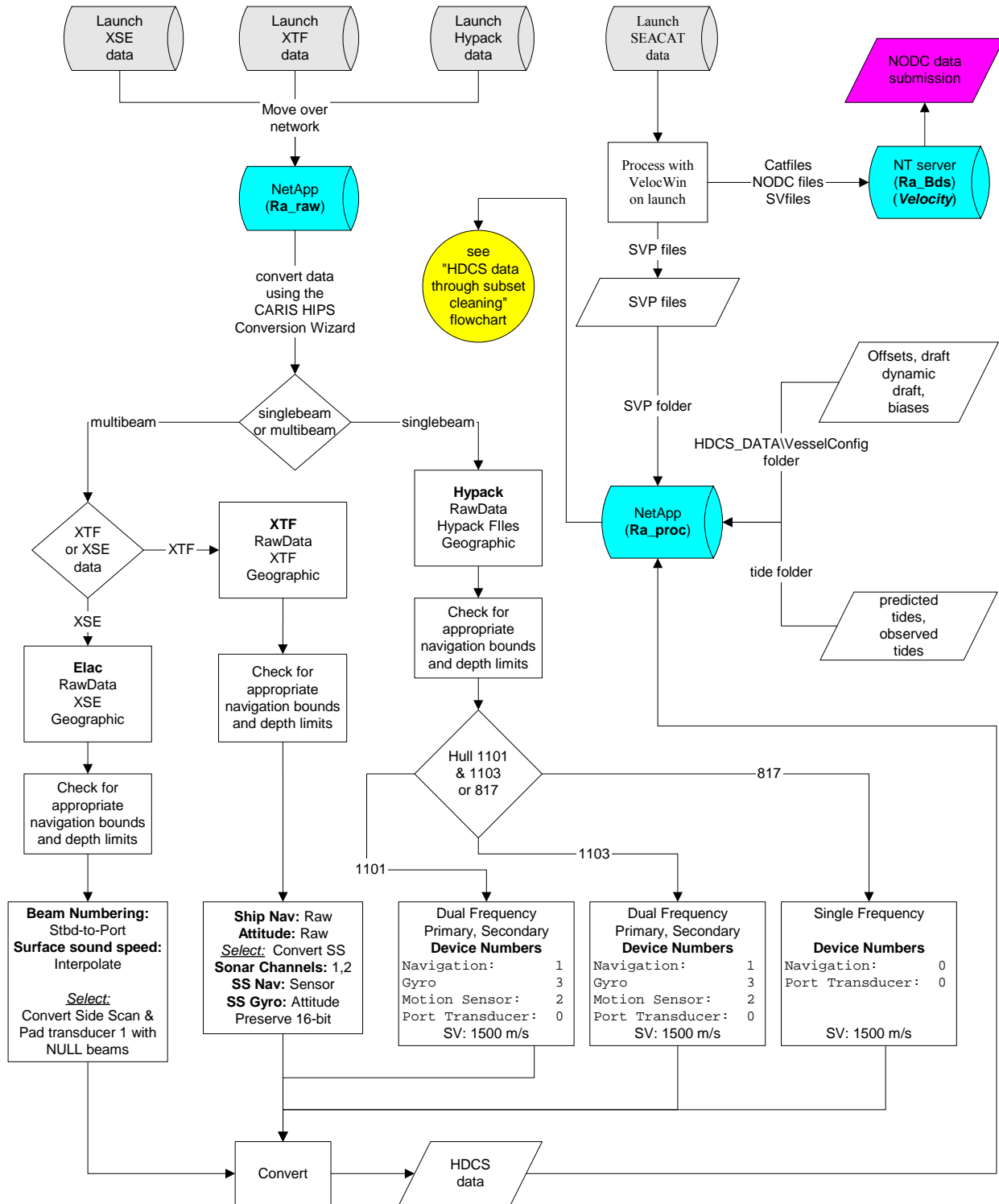
Field Operations Officer:

Benjamin K. Evans
Lieutenant, NOAA

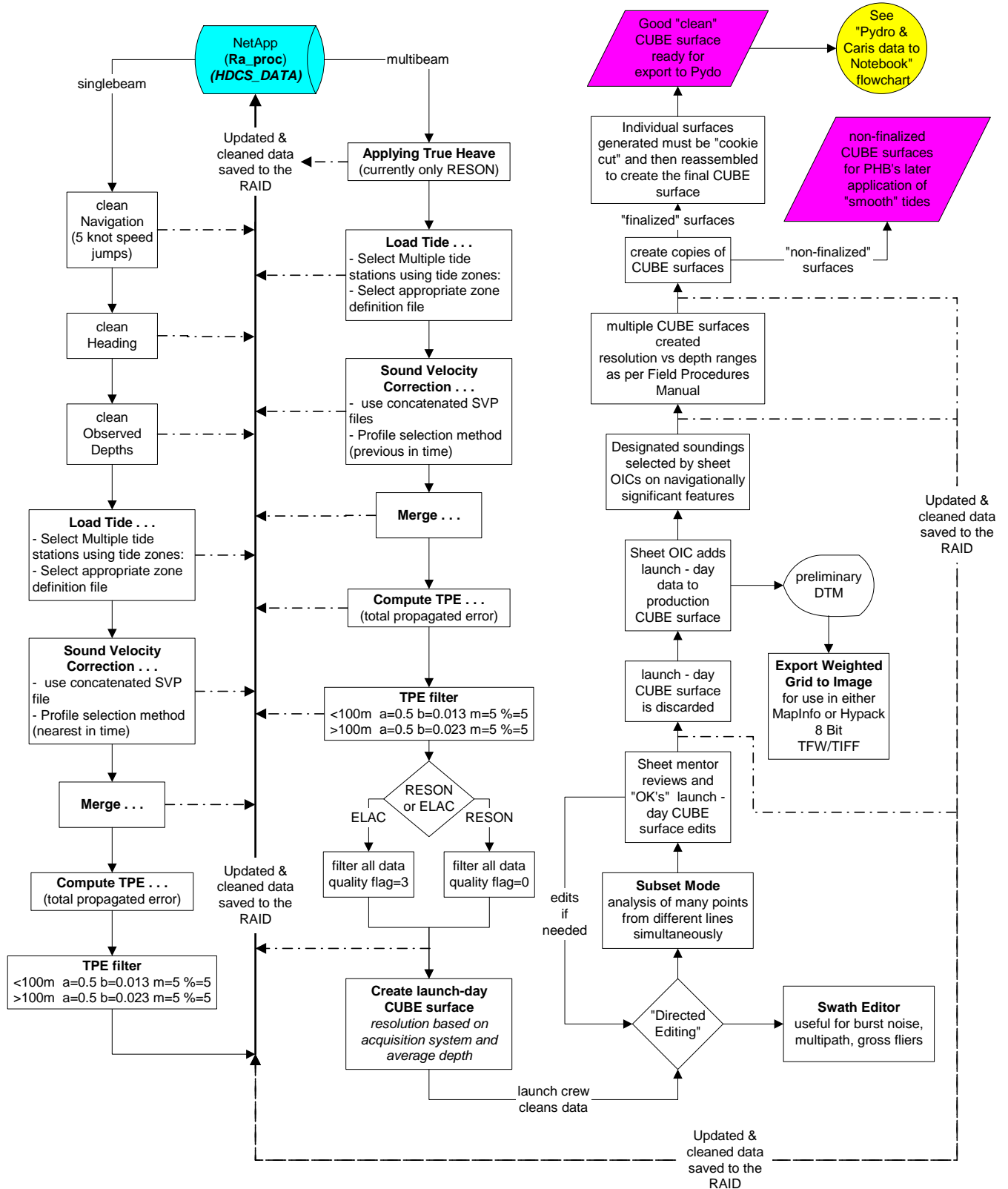
APPENDIX I

Data Processing Flow Diagrams

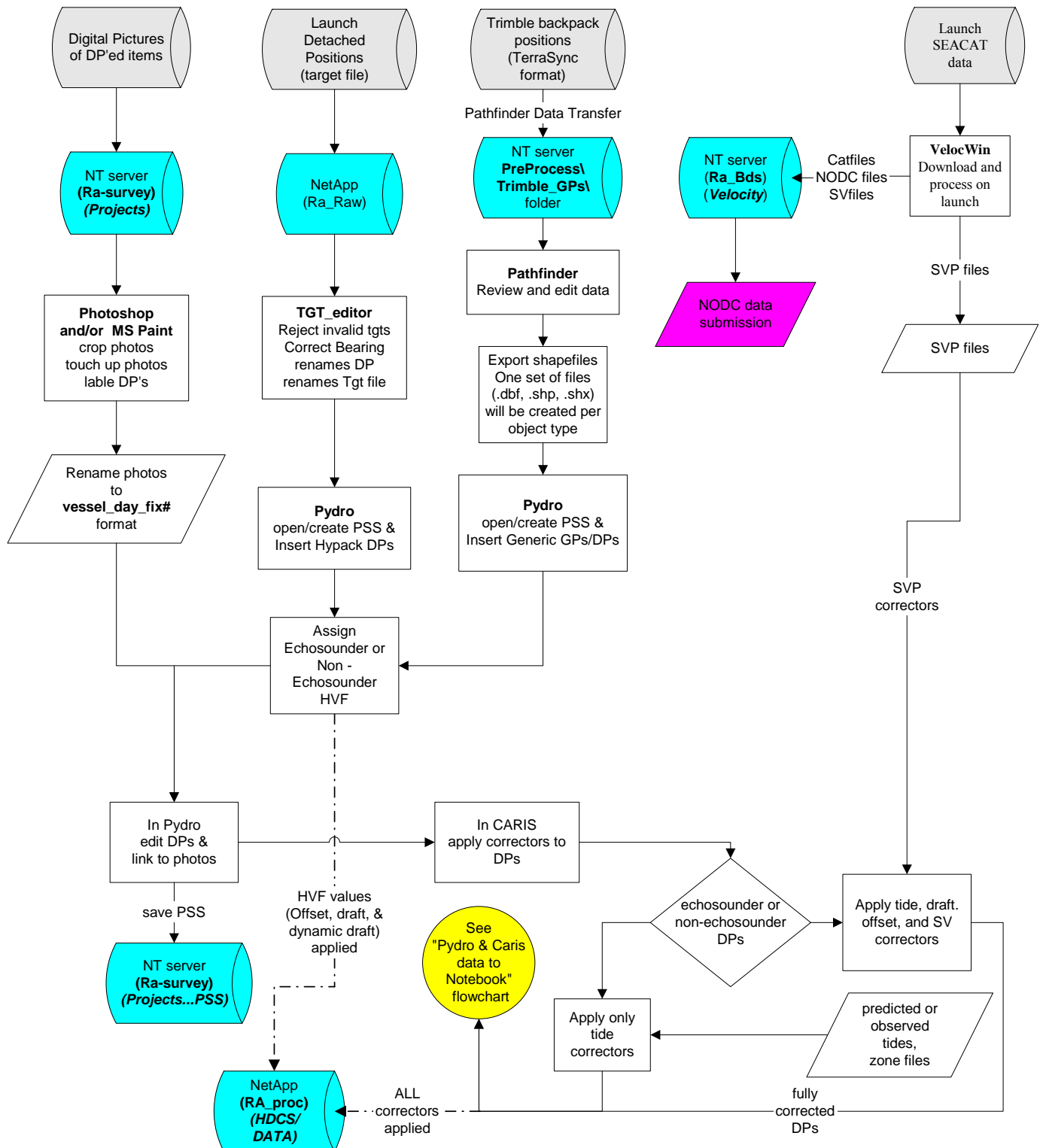
Raw sounding data to HDCS



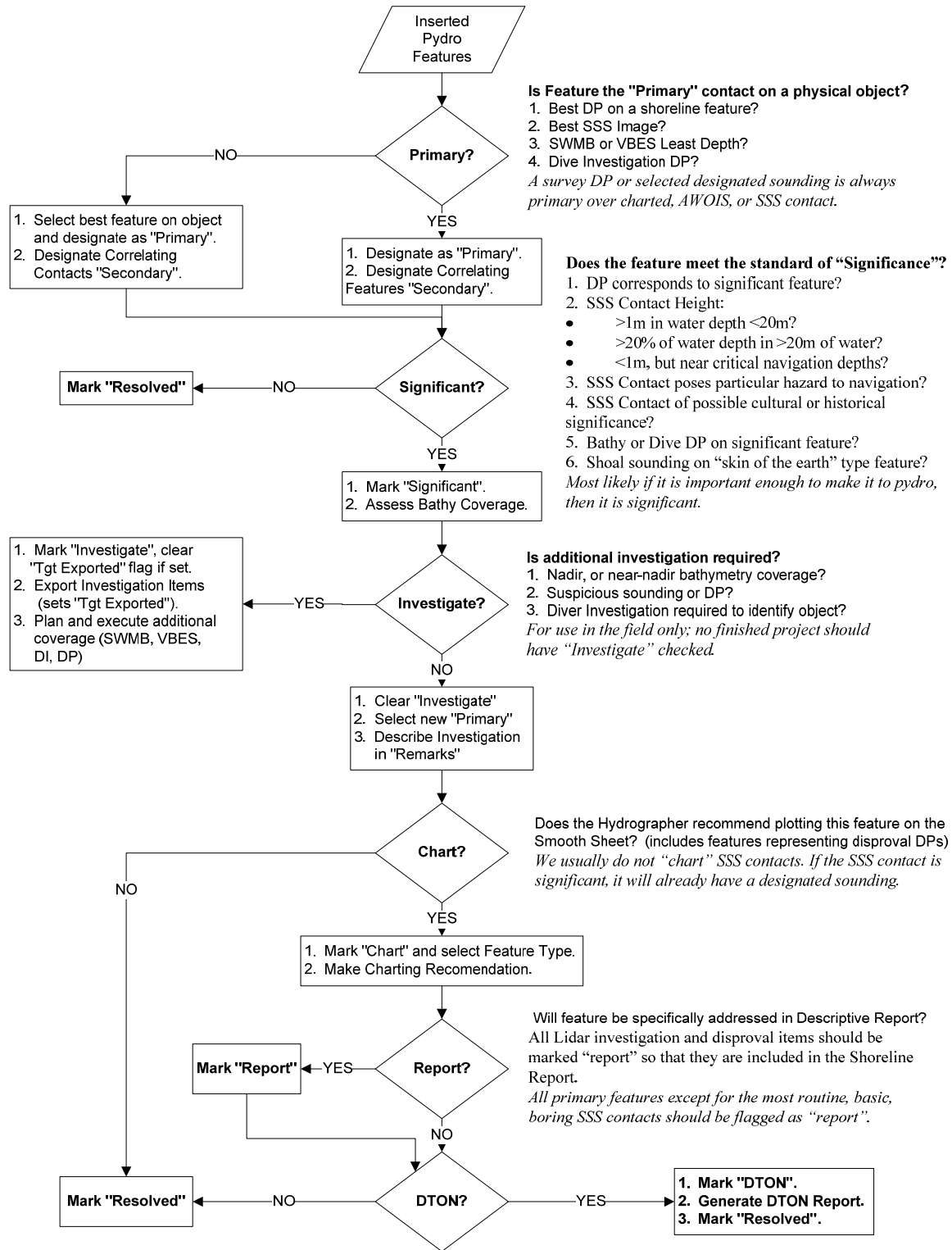
HDCS data through subset cleaning



Detached Position processing (Raw DP's to Pydro)



Detached Position and Side Scan contact processing in Pydro



Pydro & Caris data to Notebook

