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

# Data Acquisition and Processing Report

*Type of Survey* Hydrographic

*Project No.* OPR-O112-RA-07

*Time Frame* April - July 2007

## LOCALITY

*State* Alaska

*General Locality* Approaches to Sitka

**2007**

**CHIEF OF PARTY**
Commander Guy T. Noll, NOAA

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# Data Acquisition and Processing Report
## NOAA Ship RAINIER (s221)

OPR-O112-RA-07
Approaches to Sitka,, Alaska
Hydrographic Survey Project Instructions dated March 28, 2007
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 |
| 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. Vessels 1101 and 1103 are used to collect vertical-beam echosounder (VBES) data and detached positions (DPs). 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 *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package*.

Seven different categories of echosounder systems were utilized for project OPR-O112-RA-07. The individual system(s) chosen for use in a given area were decided at the discretion of the Hydrographer using the guidance stated in the Hydrographic Survey Project Instructions, the Hydrographic Surveys Specifications and Deliverables Manual (HSSDM), and the Field Procedures Manual, and depended upon the limitations of each system, the bottom topography, the water depth, and the ability of the platform vessel to safely navigate the area. These systems are described in the following section.

A complete description of all echosounder systems, positioning, and attitude sensors in addition to a complete inventory and list of serial numbers is located in the *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package.*

**Sounding Equipment:**

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

Vessels 1021 and 1006 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$^o$ swath, consisting of 101 individual 1.5$^o$ x 1.5$^o$ beams. This system was used to obtain full-bottom coverage in depths generally from 4 meters to 150 meters, with varying range scale values dependent upon the depth of water and across-track slope. 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.

On May 3, 2007 survey launch 1021 lost her Reson 8101 ER transducer due to a probable deadhead strike. The transducer was eventually replaced with a transfer from RA5 (1006) on June 30, 2007 after RA5 blew a hole in her engine block.

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 and Intermediate-Depth Multi-beam

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 sub-fans 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 utilized for collecting croslines, the system is operated in 86° (72 beams) mode to minimize "flutter" in the outer beams. Surface sound velocity is 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 for main scheme bathymetric coverage where few features are expected 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. Teledyne Benthos C3D-LPD Side Scan Sonar Bathymetry System

Vessel 1015 is equipped with a hull-mounted Benthos C3D-LPD phase differencing bathymetric sonar. The C3D is a 200 kHz system designed to produce both bathymetry and imagery across a swath 10-12 times water depth in relatively shallow water. The system utilizes the proprietary Computed Angle of Arrival Transient Imagery (CAATI) algorithm, which is marketed to be more resistant to multipath interference than traditional interferometric methods. Range scale can be adjusted between 25 and 300m, however RAINIER operated the system exclusively on range scales less than 100m for this survey. The number of sounding samples produced per ping varies with depth, range scale, and propagation conditions, but can be upwards of 1000.

RAINIER's C3D was factory modified from the standard configuration to house all electronics in the topside unit so that there are only transducers in the subsurface assembly. Each transducer is mounted with a depression angle of 30 degrees and consist of a combination 1-element transmit transmitter element and a 6-element receive array. The transducer assembly is mounted on a sled on Vessel 1015 in place of the Klein 5500 high speed, high resolution side scan sonar previously carried. (See Figure 1)

*Figure 1. Teledyne Benthos C3D-LPD Phase Differencing Sonar, as installed on Launch 1015 (RA-6)*

The C3D has been provided to RAINIER for operational test and evaluation of the sonar itself, development of data processing and management procedures, and assessment of the system's place within NOAA's suite of hydrographic tools. As the system is still in an experimental status and its bathymetry has not been shown to meet NOAA standards, all C3D depth data have been processed separately from approved SWMB bathymetry. BASE surfaces computed from C3D data are included with the survey records for evaluation purposes only.

5. 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 131º (116 beams) or 108º (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.

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 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 January 2007. Calibration reports are included in the *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package.*

**Side Scan Sonar:**

1. Teledyne Benthos C3D-LPD Side Scan Sonar Bathymetry System

As described in the Sounding Equipment section above, Vessel 1015 is equipped with a Benthos C3D-LPD phase differencing bathymetric sonar. Although the bathymetry produced by this system is not yet fully approved, C3D side scan sonar imagery was used to aid in object detection and recognition in the near-shore environment as described in the Descriptive Report. The C3D was operated at speeds less than 5 kts to ensure adequate along-track coverage, and confidence checks with survey features confirmed that the system meets NOAA side scan sonar object detection standards when operated at this speed.

The hull-mounted configuration of the C3D 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 a tow-line entanglement and operate in and around small features.

2. 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.

3. 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 1016, 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 1101 and 1103 are equipped with a Trimble DSM212L GPS receiver. 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 spot checked at any sign of trouble 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

To measure and calculate position, vessels 1015 (prior to DN192) and S221 were equipped with a TSS POS/MV 320 (version 3) while vessels 1021, 1016, 1006 and 1015 (from DN192 onward) were equipped with TSS POS/MV 320 (version 4) Position and Orientation Sensors. The switch from the POS/MV version 3 to a version 4 on RA6 (1015) occurred after the failure the original POS/MV system. At that time RA5 (1006) was sitting in the davits disabled with a blown engine and her POS/MV version 4 was available for transfer into RA6 (1015).

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 Meridian Surveyor / DMS-05

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.

2. 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 launch’s Trimble GPS to apply both latitude and vessel speed correctors. The MAHRS has a dynamic heading accuracy less than ±0.1° and a static error less than ±0.5°. The roll and pitch resolution is 0.1° with an accuracy of 0.03° at less that 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.

3. Applanix POS MV

RAINIER (S221) and her SWMB launches 1021, 1016, 1006 and 1015 (from DN192 onward) are equipped with TSS POS/MV Model 320 version 4 (version 3 in the case of S221 & 1015 prior to DN192) Position and

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

Applanix "TrueHeave" values were also recorded. The TrueHeave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. The TrueHeave data were applied to Reson bathymetry in CARIS HIPS post processing. 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-Elics' ISIS software and logged in the Extended Triton Format (XTF). Reson bathymetry was logged in the XTF file in "0x18 RI_Theta" format.

Launches 1016, 1015, and S221 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.

Launch 1015 recorded Benthos C3D SWMB & SSS echosounder data, along with position and attitude data from the POS/MV using Triton-Elics' ISIS software version 7.0.427.33 and logged in the Extended Triton Format (XTF).

Launch 1101 recorded Klein side-scan-sonar data, along with position, heading, and layback, using Klein's SonarPro software. Data were logged in the Sonar Data Format (SDF), the native format of the SonarPro software. The SDF file format was chosen over that of the XTF format due to its ability to log true heading instead of just "course made good" values.

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

All SSS data were processed using the CARIS Sonar Image Processing System (SIPS) and the Side Scan Editor software version 6.1 for the Microsoft Windows environment.

All VBES data were acquired using Coastal Oceanographic's HYPACK MAX version 6.2 SP1 or 6.2A, 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 *2007 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 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

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

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.

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

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

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, Reson SeaBat 8125 and the Teledyne Benthos C3D-LPD sonar systems. The Elac HydroStar online bathymetry data display was monitored in real-time for the Elac 1180 and 1050D. Adjustable user parameters common for Reson and Elac sonar systems are range scale, power, gain, and pulse width. Absorption loss, and spreading loss are additional user parameters used during acquisition for the Elac sonar systems. Range scale and gain parameters are also user adjustable parameters in the Benthos C3D sonar system. Swath width and bottom slope type are additional parameters used during acquisition for the C3D system. 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 6.1. The CUBE algorithm generates a surface consisting of multiple hypotheses that represent the possible depths at any given position. The CUBE surface is a grid of estimation nodes where depth values are computed based on the horizontal and vertical uncertainty of each contributing sounding as follows:

- Soundings with a low vertical uncertainty are given more influence than soundings with high vertical uncertainty
- Soundings with a low horizontal uncertainty are given more influence than soundings with a high horizontal uncertainty.
- Soundings close to the node are given a greater weight than soundings further away from the node.

As soundings are propagated to a node, a hypothesis representing a possible depth value is developed for the node. If a sounding's value is not significantly different from the previous sounding then the same or modified hypothesis is used. If the value does change significantly, a new hypothesis is created. A node can contain more than one hypothesis. As node-to-node hypotheses are combined into multiple surfaces through methodical processing, a final surface that is the best representation of the bathymetry is created.

Any individual sounding's uncertainty, or Total Propagated Error (TPE), is derived from the assumed uncertainty in the echosounder measurement itself, as well as the contributing correctors from sound speed, water levels, position, and attitude. TPE values for tide and sound velocity must be entered for each vessel during TPE computation (see table #1).

- **Tide values measured** uncertainty value is the RSS of the error estimates associated with each six minute tidal value.
- **Tide values zoning** is provided in the Tide Requirements report for each project at the 95% confidence level, and includes the estimated gauge measurement error, tidal datum computation error, and tidal zoning error. Since this tidal error value is given for 2 sigma, the value must be divided by two before it can be entered into CARIS (which expects a 1 sigma value).
- **Sound speed value measured** error ranges from 0.5 to 4 m/s, dependent on temporal/spatial variability. Although Hydrographic Surveys Technical Directive 2007-2 recommends a value of 4 m/s when 1 cast is

taken every 4-hours, RAINIER experience in the field suggests that a value of 0.5 m/s better models this error.

- **Sound speed value surface** for flat face transducers such as the Reson 8125 and the Elac 1180 on vessels 1016 and 1015 is 0.3 m/s due to use of the Odom Digibar Pro. A value of 0.25 m/s is used for RAINIER and her Sea-Bird SBE 45 thermosalinograph. All other launches that have no real time sound speed correctors at the transducer face use a value of 0.0 m/s.

| Vessel | Tide values measured | Tide values zoning | Sound speed values measured | Sound speed values surface |
|---|---|---|---|---|
| 1006_Reson8101_HVF | 0.01 | 0.05 | 0.50 | 0.00 |
| 1015_Elac1180_HVF | 0.01 | 0.05 | 0.50 | 0.30 |
| 1015_C3D_HVF | 0.01 | 0.05 | 0.50 | 0.30 |
| 1016_Elac1180_HVF | 0.01 | 0.05 | 0.50 | 0.30 |
| 1016_Reson8125_hvf | 0.01 | 0.05 | 0.50 | 0.30 |
| 1021_reson8101_HVF | 0.01 | 0.05 | 0.50 | 0.00 |
| S221_Elac1050D_LF | 0.01 | 0.05 | 0.50 | 0.25 |
| 1101_Singlebeam_HVF | 0.01 | 0.05 | 0.50 | 0.00 |
| 1103_Singlebeam_HVF | 0.01 | 0.05 | 0.50 | 0.00 |

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

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

The exact behavior of CUBE is determined by the values set in the CUBE Parameters File (CUBEParams.xml). During the creation of CUBE surfaces the user is given the option to select parameter configurations which have been tuned by Hydrographic Systems and Technology Programs (HSTP) personnel to optimize performance of the CUBE algorithm (HSTD 2007-2). The CARIS "Default" configuration is not authorized for NOAA surveys and has been disabled in the CUBEParams.xml file to prevent misapplication. The "Deep" configuration corresponds to the NOAA "Complete" survey requirements and is typically chosen for CUBE surfaces created for depths greater than 30-meters. The "Shallow" configuration corresponds to the NOAA "Object Detection" survey requirements and is typically selected for CUBE surfaces created for depths less than 30-meters. The modified CUBEParams.xml file is stored in the central CARIS VesselConfig directory and is submitted with each survey.

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, Benthos XTF, or Elac XSE data to the HDCS data format.
2. Load predicted tides.
3. Load and apply sound velocity files.
4. "Merge" data to apply position, attitude, vessel offsets, and dynamic draft correctors to bathymetry and compute the corrected depth and position of each sounding.
5. Compute TPE.
6. Filter data according to the following criteria:

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

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

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

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

7. Add the data to a temporary boat-day field sheet and multi-resolution CUBE BASE surface for each sheet on which that boat acquired data.
   - Field Sheet naming convention: Hxxxxx_<vessel>_<DN> (e.g., H12345_1006_DN123)
   - BASE Surface naming convention: Hxxxxx_<vessel>_<DN>_MR (e.g., H12345_1006_DN123_MR)
   - Boat-day field sheets are kept as small as possible since CARIS allocates memory for any empty space which slows down processing. Field sheets are created big enough to cover the full extents of the MBES swaths of the day's data, but not bigger than necessary.
   - Multi-resolution grid depth-resolution ranges are set in accordance with standard practice:

| Depth Range Filtering | CUBE Surface Resolution |
|---|---|
| 0 - 16 m | 0.5 m |
| 14 – 31.5 m | 1.0 m |
| 28.5 – 63 m | 2.0 m |
| 57 – 158 m | 5.0 m |
| 143 m + | 10.0 m |

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

   - The CUBE parameters selected are based on what is most appropriate for the majority of the data, using 30 m depth as the cutoff between "Shallow" and "Deep".

Practical experience aboard RAINIER suggest that CUBE surfaces generated with these resolutions and depth ranges (see Table 2, above) capture most of the bathymetric high points without burdening the processing pipeline with resolutions so high that they are neither supported by the actual data nor practical in terms of computational time or file size. Unresolved problems with the CARIS multiple resolution algorithm results in poor junctions at the resolution steps but an overlap of ~10% of the depth (i.e., +/-5%) appears to yield usable results for cleaning and planning purposes.

The following options are selected when CUBE surfaces were created:

- **Surface Type** – CUBE
- **IHO S-44 Order** – Order 1
- **Include status** – check Accepted, Examined and Outstanding
- **Disambiguation method -** Density & Locale (this method selects the hypothesis that contains greatest number of soundings and is also consistent with neighboring nodes).
- **Advanced Configuration** – "Shallow" if the bulk of soundings are less than 30m, "Deep" if the bulk of soundings are over 30 meters.

Preliminary data cleaning is performed daily using the Boat-Day CUBE surface as a guide for "directed editing". Depth, Standard Deviation, Hypothesis Strength and Hypothesis Count models derived from the boat-day surface are viewed with appropriate vertical exaggeration and a variety of sun illumination angles to highlight potential problem areas. Based on this analysis the most appropriate cleaning method is selected as follows:

- Subset Mode is the default tool selected due to its ability to quickly compare large numbers of soundings with adjacent or overlapping data for confirmation or rejection. Subset mode also excels with the assessment of possible features, disagreement between overlapping lines, and crossline comparison. The image designer can be used to visually enhance patterns and anomalies in CUBE surfaces, especially the standard deviation CUBE surface.
- Swath Editor is useful for burst noise, multipath, and other "gross fliers" which are specific to a particular line or lines, and most easily removed in this mode. Additionally, when it was felt that the quality of the data was reduced due to environmental conditions such as rough seas or extreme variance in sound velocity, data were filtered on a line by line basis to a lesser swath width to ensure data quality.
- Both modes (but particularly Swath Editor) are used as a training aid to help novices learn how the various sonars operate, and provide feedback to the acquisition process.

With the advent of CUBE-based processing, it has become possible to adjust the final bathymetric surface directly by selecting the correct hypothesis to use. Although this method is available, it is standard practice on RAINIER to clean soundings in the traditional method until the CUBE algorithm selects the correct hypothesis.

Once all the data from all launches is clean, it is added to the affected “constant maintenance” CUBE surfaces. These “constant maintenance” CUBE surface are a group of fieldsheets tiled in such a way as to keep the CUBE surfaces small enough for rapid computation. These CUBE surfaces use the “Rainier standard” set of grid depth-resolution ranges (see Table #2 above) and are used to ensure bottom coverage and plan additional lines. In addition these “constant maintenance” CUBE surfaces are used to compare adjacent lines and crosslines, for systematic errors such as tide or sound velocity errors, sensor error, sonar errors (consistent bad beams), vessel configuration problems, and noise. Any irregular patterns or problems are reported immediately to the FOO and the Survey manager so that remedies can be found and applied before more data are acquired. These CUBE surfaces are maintained as follows:

- Each sheet manager is responsible for setting up the constant maintenance field sheets. There will be approximately 6 to 8 for each survey sheet, named sequentially. (e.g. “H12345_A”, “H12345_B”, etc.)
- If there is already a BASE surface in the field sheet, the processing crew checks to see if it is out of date (“broken”). If it is not, add the new data by using the “Add to BASE Surface” function.
- If the BASE surface is broken or does not exist (i.e., this is the first day of acquisition in that field sheet), the old BASE surface is deleted and a new one created.
    - Multi-resolution parameters are used from the table #2 above.
    - CUBE parameters are selected which are most appropriate for the majority of the data, using 30 m depth as the cutoff between “Shallow” and “Deep”.
    - The naming convention for the CUBE surfaces is “Hxxxxx_<letter>_MR”, e.g., H12345_A_MR for the first field sheet of the survey.

A coarse 10m resolution “Launch” BASE surface is also maintained for use in the survey launches during data acquisition. The 10m resolution was selected to maintain smaller, easily moved GeoTiff files.

- Naming convention is Hxxxxx_Launch_10m.
- The surface is created as a single resolution CUBE surface at 10m resolution.

- The CUBE parameters are selected based on which are most appropriate for the majority of the survey data, using 30 m depth as the cutoff between “Shallow” and “Deep”.
- A daily GeoTiff file of each sheet also saved to aid in compilation of public relations products.

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

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

At the time of this report, Coast Survey has not approved multiple resolution BASE surfaces as a final deliverable. Although these surfaces are acceptable for field use, the algorithm produces artifacts at the resolution steps that are unsuitable for a final product. To circumvent this problem, single resolution CUBE surfaces were generated to be “cookie cut” and then reassembled to create the final CUBE surface from which depths are derived. Multiple CUBE surfaces are gridded using different resolutions for different depth ranges (see table 2). Under ideal circumstances gridding should be done at the finest resolution that the data density will support. This theoretical maximum resolution is often defined as three times the beam footprint size for a particular echosounder and depth combination. In practice, RAINER adheres to a table of resolutions and depth ranges gained through practical experience in “typical” survey areas, and a working knowledge bottom coverage capabilities of each echo sounding system in use. These resolutions are also based on assumed sonar system selections for each depth regime and practical data processing limitations. Typically, deeper areas are gridded at a coarser resolution than shoaler areas where the data density is greater.

Finalized CUBE surfaces fit for submission can only be created 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 shown in table 2. All CUBE surfaces are then combined at the coarsest resolution used to create the final combined CUBE surface. The final, combined CUBE surface should be named Hxxxxx_Final_Combined_Xm and be created in the survey wide field sheet Hxxxxx.

The final CUBE surfaces are sun-illuminated from different angles and examined for coverage and as a final check for systematic errors such as tide, sound velocity, or attitude and/or timing errors. The final CUBE surface submitted in the fieldsheet serves to demonstrate that both SWMB coverage requirements are met and that systematic errors have been examined for quality-assurance purposes.

As a quality control (QC) measure, a number of cross-lines greater than 5% of mainscheme lines were run on each survey and manually compared to the mainscheme lines in CARIS subset mode. This qualitative QC comparison is discussed in the descriptive report for each survey.

### 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 the 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 digitization. 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.

### Feature Data

Source shoreline data for this project was supplied by N/CS31 in a single Composite Source Shoreline file in CARIS notebook HOB format (OPR-0112_RA-07, Sitka.hob). Additionally, a Discrepancies file (OPR-0112_RA-07 Discrepancy.hob) was supplied with the project instructions containing AWOIS items and any other features specifically tasked to RAINIER for investigation. Finally, RAINIER personnel imported the sheet and survey limits into a Reference .hob file. These project-wide .hob files were trimmed to the survey limits by the survey managers. These sheet-specific files were exported to .000 format for display in Hypack on the survey launches, and printed from CARIS Notebook to create paper boat sheets for reference and note-taking during shoreline verification operations. This process is described in detail in the "CARIS Notebook" section below.

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

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

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

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

As the approximate NALL line was run along the shore, the hydrographer both annotated the shoreline reference document and scanned the area for features to be addressed. Feature types to be addressed were as follows:

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

- Inshore of the NALL:
  - Navigationally significant features only, as defined below.

Navigationally Significant" features were defined as the following:

- All features within the limits of safe navigation (i.e., offshore of the NALL).
- Features inshore of the NALL which:
  - are sufficiently prominent to provide a visual aid to navigation (landmarks). Note that rocks awash are almost never landmarks, but distinctive islets or other features visible at MHW can be useful for visual navigation.
  - significantly (a ground unit distance equivalent to 0.8mm at the scale of the largest scale chart of the area) deflect this limit. 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 were not generally considered navigationally significant. Areas with a high density of mooring buoys for these vessels were delineated, but the features themselves not individually positioned.

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

**“Noted”**

- The existence of a feature and its characteristics were confirmed from a distance, and its position appeared to be correct within the scale of the chart or source.
- Appropriate for features inshore of the limit of hydrography and not navigationally significant, significant features that require no further investigation, or features unsafe to approach to verify position within survey scale.
- Noted features were annotated on the shoreline reference document but carried no further forward in the processing pipeline. A feature whose presence is "noted" is not included in the H-Cell and adds little to PHB’s current evaluation and verification process.

**“ Verified "**

- The feature’s position and characteristics were acquired and recorded either by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning was generally by DGPS methods.
- Appropriate for 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) was either unknown or incorrect. **This position should not supersede that of the source data, so it was 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.** To avoid this potential for confusion, it is a common practice is to “fudge” the range and bearing of a **“DP for Height”** to coincide with the position of the feature in question.
- Appropriate for source features found within 20m of their source positions, but with incorrect or missing height or depth data.

**“New"**

- The feature’s position and attributes (including height) were acquired and recorded either by directly occupying the site, or by applying a range and bearing offset to a known position. Positioning was generally by DGPS methods.
- Appropriate for items seaward of the NALL that are not present in the Composite Source.
- Items inshore of the NALL which are navigationally significant and are not present in source data.

**“Not Seen”**

- The feature was present in source data (chart, DCFF, etc.) but was not visually observed in the field. Full disproval search (see below) was **not** conducted.
- Appropriate for:
    - Features above MHW, the absence of which can be proven visually from a distance.
    - Source features inshore of the limit of hydrography which are not observed, but whose presence on or absence from the survey will not affect safe navigation.
    - Any feature from source which was not seen, but for which full disproval search (see below) is impractical or unsafe.

**“Disproved”**

- The feature was present in source data, but was not located after a full search. “Full Search” means SWMB, VBES, SSS, and/or Detached Position coverage of the area which conclusively shows that the item is not located at the position given to the accuracy and scale of the source document.

The primary purpose of detached positions (DPs) is to verify and define shoreline features (ex: rocks, reefs ledges, piles), disprove charted features, position navigational aids and landmarks (ex: buoys, beacons, lights), and mark positions of bottom samples. 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 118$^{th}$ 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 four 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.
- 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” 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 transfer to Notebook were flagged "Chart" in Pydro.

**Pydro Feature Extraction**

Pydro features are exported as Extensible Markup Language (XML) files for use in CARIS Notebook by selecting **Data → Export → XML Feature Data**. Pydro feature data is sorted by using export filters in pre-configured filter templates created by Rainier personnel. By using both Pydro Keywords and CartoAction flags, features are sorted into XML files for later import as CARIS Notebook HOB files. The naming of the XML export files coincides with the Notebook HOB files that will be created.

| XML file | Feature Query Tree |
|---|---|
| HXXXXX_Pydro_Updates | Features – Primary - CartoActionAdd<br>Features – Primary - CartoActionModify |
| Hxxxxx_Disprovals | Features – Primary - CartoActionDelete |

***Table 3 Feature tree filters required for XML export files***

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**

Beginning with the 2007 field season, the composite source shoreline feature file created at HSD and delivered with the project instructions is to be used as the only shoreline data available for use in the field. The composite source file is compiled from all available source shoreline files (i.e. ENC, Geographic Cells, LIDAR, RNC, and Prior Surveys) into a single file in an S-57 .000 format. Due to the necessity of training shipboard personnel and troubleshooting the implementation of this new processing pipeline, HSD personnel were aboard RAINIER throughout project OPR-O112-RA-07 and created a composite source file in HOB format while in the field.

By populating the source indicator (SORIND) and source date (SORDAT) fields, the original source of any feature may be queried. All features that require further field investigation (i.e. AWOIS and LIDAR Investigations) are delivered in a separate file called **Discrepancy**.

In preparation for shoreline verification, the Survey Manager copied the project wide composite source file and cropped it to include only items contained on their assigned sheet. This cropped file is then saved as a HOB file named **HXXXXX_Original_Comp_Source.HOB**. At this point no further edits are ever made to this HOB file and it is retained as the "starting point" to any subsequent changes discovered during shoreline verification. The **HXXXXX_Original_Comp_Source.HOB** is also saved in an S-57 .000 format which can be directly opened in Hypack.

The Survey Manager next creates a composite shoreline reference document, the paper representation of the shoreline that will be used to write observations in the field. The HXXXXX_Original_Comp_Source.HOB file is color coded by source using the SORIND source indicator and sent directly to the plotter from Notebook.

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

Composite source features offshore of the NALL which were DPed for height were also de-conflicted if multiple shoreline features from were present representing the same item. The source item most closely representing the actual feature was retained in the **HXXXXX_FieldVerified _Source HOB** while the other extraneous features were moved into **HXXXXX_Deleted_Source.HOB.** In the event that a DP was taken to reposition an incorrectly charted feature, all of the composite source feature in the wrong position were moved into **HXXXXX_Deleted_Source.HOB.**

For surveys where limited shoreline verification was performed, DP/GPs and/or Caris VBES/SWMB CUBE surfaces were used to help define kelp and foul areas. Any new line features were digitized in the **HXXXXX_Field_Verified.HOB** file. Deleted sections of line features and/or any items fully deleted are moved to the **HXXXXX_Deleted_Source.HOB** file for tracking purposes. In all cases, when objects were added or modified the SORDAT and SORIND fields were updated. As a last step after final tides have been applied, filters were used in the Pydro to XML step before the Notebook import to create both **HXXXXX_Pydro_Updates** and **HXXXXX_Disprovals.** The Notebook HOB files submitted as each individual survey's shoreline deliverables are:

- **HXXXXX_Original_Comp_Source –** The unedited source shoreline file, compiled at Operations with no deconfliction and including all available shoreline sources (with appropriate source attribution, SORIND).
- **HXXXXX_FieldVerified_Source –** This file is a copy of the original composite source HOB file that has been edited to represent the shoreline as seen in the field during shoreline verification. This editing includes de-confliction where all unnecessary duplicate features have been removed. The field unit verifies only features within the survey limits (i.e. seaward of the NALL or deemed navigationally significant). If a feature within the survey limits has multiple sources, then the hydrographer picks the most accurately charted feature and removes the other source feature(s). This file also includes all new line features (kelp, foul limits, ledges, etc) and any source features that have been modified with the assistance of the VBES buffer line or GPs taken to delineate new extents.
- **HXXXXX_Deleted_Source** - This layer serves as a means to keep track of all the source features deleted from the Field Verified Source layer. Features may be deleted from the Field Verified Source because they were disproved with SB or MB Echosounder or removed during de-confliction.
- **HXXXXX_Pydro_Updates –** DP/GPs taken on new features or to update source features and exported from Pydro as XML files.
- **HXXXXX_Disprovals –** DP/GPs taken to disprove source features and exported from Pydro as XML files.

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 the best available tides at the time the survey is submitted.

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 8.85 (v8.86 after 5/6/07) 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 *2007 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 and the Sea-Bird SBE 45 thermosalinograph on S221.

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.

The Elac 1050D MKII SWMB system installed aboard S221 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 into the HydroStar acquisition software from an Sea-Bird SBE 45 thermosalinograph (TSG). Unfortunately, a method for ELAC to accept data directly from the TSG could not be discovered so HSTP was forced to create a conversion utility named SBEtoELAC (v1.2.0). This application receives a SBE-45 formatted string from the TSG via a selected COM port and transforms it into a ELAC formatted string. This output string is then sent out over yet another COM port for interfacing to the ELAC. 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.

RAINIER's standard practice is for each multibeam survey launch to take the CTD casts required to correct the data acquired by that launch. However, due to the multiple launches often working on the same sheet during any given day and geographically variable sound speed profiles in a fjord-like environment, it made sense to combine all CTD casts into a single ~~project~~ wide concatenated file.

All sound velocity profiles collected on any given sheet were concatenated into a single sheet-wide file in order of ascending time/date and saved in a dedicated directory located within the sheet's master SVP folder. A naming convention of *Hxxxxx_concat*.SVP was used where *Hxxxxx* is the registry number (Ex: **H11677_concat.SVP** is the concatenated SVP file of all vessels on sheet H11677). This concatenated file was then applied to all HDCS data collected with the option **Nearest in distance within time** within **3 hours** selected under the **Profile Selection Method**.

*RAINIER TSG Problems:*

In spite of frequent CTD casts, initial data collected by RAINIER exhibited "frowning" very typical of sound speed problems. After a number of lines had been run, it was realized that the TSG was reading a much higher sound velocity (~1501 m/s) than various CTD casts were indicating at the surface (~1493 m/s). The TSG values were apparently in error for an as yet unexplained reason. The problem was solved by disabling TSG values in the acquisition software and using only the CTD cast corrections present in the SVA file.

Fortunately, the lines already acquired with the faulty TSG can be corrected since CARIS is capable of re-applying the flat face refraction correction at the face at the transducer in post processing for ELAC systems. By manually deleting the "SSP" files (SSP, SSPLineSegments, & SSPTmIdx) in the HDCS data folder, CARIS can be tricked into thinking that no flat face refraction correction was preformed during acquisition. Thus during the SV correction phase in CARIS, both flat face refraction correction and the ray tracing correctors

## 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 *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package.*

| Vessel Hull Number | Date of Static Draft and Transducer Offset Measurements | Method of Settlement and Squat Measurement | Date of Settlement and Squat Measurement | Location of Settlement and Squat Measurement |
|---|---|---|---|---|
| 1101 | April 2007 | Optical Level | March 30, 2007 | Lake Washington, WA |
| 1103 | April 2007 | Optical Level | March 30, 2007 | Lake Washington, WA |
| 1021 | April 2007 | Surface analysis | April 2, 2007 | Lake Washington, WA |
| 1016 | April 2007 | Surface analysis | March 27, 2007 | Lake Washington, WA |

| | | | | |
|---|---|---|---|---|
| 1006 | April 2007 | Surface analysis | March 28, 2007 | Lake Washington, WA |
| 1015 | April 2007 | Optical Level | April 5, 2007 | Lake Washington, WA |
| S221 | April 2003 | OTF* | March 1999 | Port Angeles, WA |

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

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

Settlement and squat observations were conducted for launches 1021, 1016 and 1006 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 launches 1101, 1103, and 1015. The procedure followed that outlined in the FPM (1.4.2—Vessel Dynamic Offsets). One line drawn in Lake Washington was used to acquire the data. After the initial first line was run at 1000RPM, the speeds thereafter increased at 200-RPM increments. The vessel was run perpendicular to the pier since running parallel to the pier made reading the rod very difficult. Port and starboard values were averaged at rest and for each speed ran. The difference between the average at rest readings and the average of the port and starboard underway readings produced the values for the settlement and squat speed curves.

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 with more than one acquisition method 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 bathymetric data in CARIS during post-processing. Vessel offset diagrams and dynamic draft tables are included in included in the *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package*. The HVFs themselves are submitted with the digital HDCS data.

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

| **HVF name** | **Survey Vessel & System Type** |
|---|---|
| 1006_Reson8101_HVF | Jensen hull 1106, SWMB using hull mounted Reson 8101 |
| 1015_C3D_HVF | Jensen hull 1015, SWMB & SSS using hull mounted Benthos C3D-LPD |
| 1015_Elac1180_HVF | Jensen hull 1015, SWMB using hull mounted Elac 1180 |
| 1016_Elac1180_HVF | Jensen hull 1016, SWMB using hull mounted Elac 1180 |
| 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 depth |
| 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_nonechosounder_dp | Jensen hull 1103, detached positions not using echosounder |

| | |
|---|---|
| 1103_Singlebeam_HVF | Jensen hull 1103, singlebeam using Knudsen 320M |
| S221_Elac1050D_HF | Ship hull S221, high freq. SWMB using hull mounted Elac 1050D MKII |
| S221_Elac1050D_LF | Ship hull S221, low freq. SWMB using hull mounted Elac 1050D MKII |

***Table 5 List of HVFs used for project OPR-O112-RA-07***

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

Attitude and Heave data were measured with the sensors described in Section A, and applied in post-processing during SVP Correct and Merge in CARIS HIPS.

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

RAINIER's SWMB equipped survey launches utilize a heave filter integration method known as "TrueHeave" as described in Section 3 of the OCS Field Procedures Manual. This dramatically reduces the filter settling time as compared to the traditional heave filter, almost completely eliminating the need for steadying up on lines before logging can begin.

TrueHeave data were logged throughout the survey day, independent of line changes. Each vessel's TrueHeave files were saved in the "POS" folder of the CARIS preprocessed data drive (ex: H:\OPR-O112-RA-06_Sitka\H11128\POS\1016\DN148 contains TrueHeave data collected by vessel 1016 on day number 148 for sheet H11128). After regular CARIS data conversion this TrueHeave file was separately loaded into HIPS, replacing the unfiltered heave values recorded in the raw XTF data.

Beginning with the v3.30 firmware update, the POS MV v4 started to produce a slightly different file format that occasionally causes problems in CARIS 6.1 while loading TrueHeave files. Ideally this problem can be avoided in the field by starting TrueHeave logging at least 3 minutes before starting bathymetric data collection, and letting it run for at least 3 minutes afterward. This is required because the filter which produces the true heave values looks at a long series of data before and after the actual collection time of bathymetric data. If there is still a problem with the TrueHeave data, the utility "fixTrueHeave" was run from the command line with the following context: **"fixTrueHeave <trueheave filename> -trim"**. This produces a new file with the same base name, but with the suffix "fixed" appended. This new ".fixed" file is then applied to the appropriate lines in HIPS.

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.

RA3 (1021) lost her Reson 8101 transducer on May 3, 2007 due to a log strike and was not used for survey until early July. On June 30, 2007 RA5 (1006) blew a hole in her engine block and was put out of service for the foreseeable future. This mechanical failure allowed the Reson 8101 transducer to be transferred from 1006 to 1021 and on July 5, 2007 (DN186) a new patch test was conducted for RA3 (1021).

On July 10, 2007 (DN191), RA6 (1015) experienced a failure or her TSS POS/MV system. The problem was eventually traced to a bad inertial measurement unit (IMU) which was replaced with the IMU from the disabled RA5 (1006). This transfer necessitated an new patch test for each acquisition system aboard RA6 (1015). This patch test was conducted on July 11, 2007 (DN192) for the Benthos C3D-LPD and on July 21, 2007 (DN202) for the ELAC 1180.

Timing and attitude biases were determined in accordance with Section 1 of the Field Procedures Manual, and are described in the *2007 NOAA Ship RAINIER Hydrographic Readiness Review Package*.

All vessel offsets, dynamic draft correctors, and system bias values are contained in CARIS HIPS Vessel Files (HVFs) and were created using the program Vessel Editor in CARIS. These offsets and biases are applied to the sounding data during processing in CARIS.

**Water Level Correctors**

For daily processing, soundings were reduced to Mean Lower-Low Water (MLLW) using predicted water levels from station Sitka, AK (945-1600) using the tide file 9451600.tid. The predicted water level data from the tide stations were applied to the survey depths in CARIS using height ratio and time correctors from the CO-OPS provided zone definition file, O112RA2007CORP.zdf supplied with the Hydrographic Survey Project Instructions.

After the conclusion of data acquisition, water levels are applied to the soundings using one of two methods, verified observed water levels using preliminary height ratio and time correctors from a CO-OPS supplied zone definition file or TCARI tides. TCARI tides are the preferred method but zoned tides using verified observed water levels may be used if the ship has not received the required TCARI grid and verified tide files. Typically the biggest holdup is getting verified six-minute water level data from subordinate tide station(s) installed by RAINIER personnel.

In the event TCARI tides are not yet available, soundings are reduced to Mean Lower-Low Water (MLLW) using verified observed water levels from station Sitka, AK (945-1600) using the tide file 9451600.tid. The 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 file (O112RA2007CORP.zdf).

If all the required files have been received by the ship in time, water levels are applied to the soundings using TCARI, the Tidal Constituent And Residual Interpolator. TCARI automatically calculates the error associated with water level interpolation. This error is incorporated into the residual/harmonic solutions and included in the Total Propagated Error (TPE) for the survey. For hydrography in project area OPR-O112-RA-2007 Approaches to Sitka, AK, TCARI grid “O112RA2007.tc” was supplied to produce a seamless tide correction. The application of TCARI tides fully supersedes the need for tidal computations using a zone definition file

The TCARI grid file is sent from CO-OPS and loaded into Pydro. Once in Pydro the TCARI grid may be examined along with the list of tide stations that affect it. TCARI utilizes all tide stations in the project area (historical and currently operating) for harmonic constants and datums. Only those stations selected in the residual column are used for residuals. Residuals are the difference between observed water levels and predicted water levels, non-tidal components such as meteorological effects. The TCARI Project Instructions sent for each project list the stations required for residuals that must be downloaded from the CO-OPS website. The operating National Water Level Observation Network (NWLON) station at Sitka, AK (9451600) served as both datum control and a source of water level reducers for this project. In addition, the subordinate station of Dorothy Cove, AK (945-1376) installed by RAINIER personnel provides information on tidal datums, water level reducers, refinement of final zoning and harmonic constituents for predictions.

Verified six-minute water level data for stations Sitka, AK (945-1600) and Dorothy Cove, AK (945-1376) were downloaded on the **MSL** datum in meters and UTC. TCARI tides are loaded and applied directly to CARIS HDCS data using Pydro. Once all required water levels are downloaded, they are loaded from the main menu bar, **TCARI > Load WL Data.** Tide reducers are generated for HDCS bathymetry from the main tool bar, **TCARI > Create HDCS Tides**. At this time HDCS data is selected by project, vessel, and day with individual lines selected with the Descend/Confirm button. TCARI then creates new “Tide”, “TideLineSegments”, and “TideTmIDX” files for each line of bathymetry. Once TCARI has created the new tide files, the lines must be re-merged in CARIS for the changes to take effect**.**

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 (March 2007 edition), NOS Hydrographic Surveys Specifications and Deliverables (April 2007 edition), and all Hydrographic Technical Directives issued through the dates of data acquisition. All departures from these standard practices are described in this Data Acquisition and Processing Report and/or the relevant Descriptive Reports.

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

Digitally signed by CDR Donald W. Haines, NOAA
DN: cn=CDR Donald W. Haines, NOAA, c=US, o=NMAO/MOC-P/RA, ou=Commanding Officer, RAINIER, email=don.haines@noaa.gov
Reason: I am approving this document
Date: 2007.10.26 18:32:01 -07'00'

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:

James B Jacobson
I am the author of this document
2007.10.26 20:46:26 Z

Chief Survey Technician: ______________________________

James B. Jacobson
Chief Survey Technician, NOAA Ship RAINIER

Charles Yoos
I have reviewed this document
2007.10.26 14:08:51 -07'00'

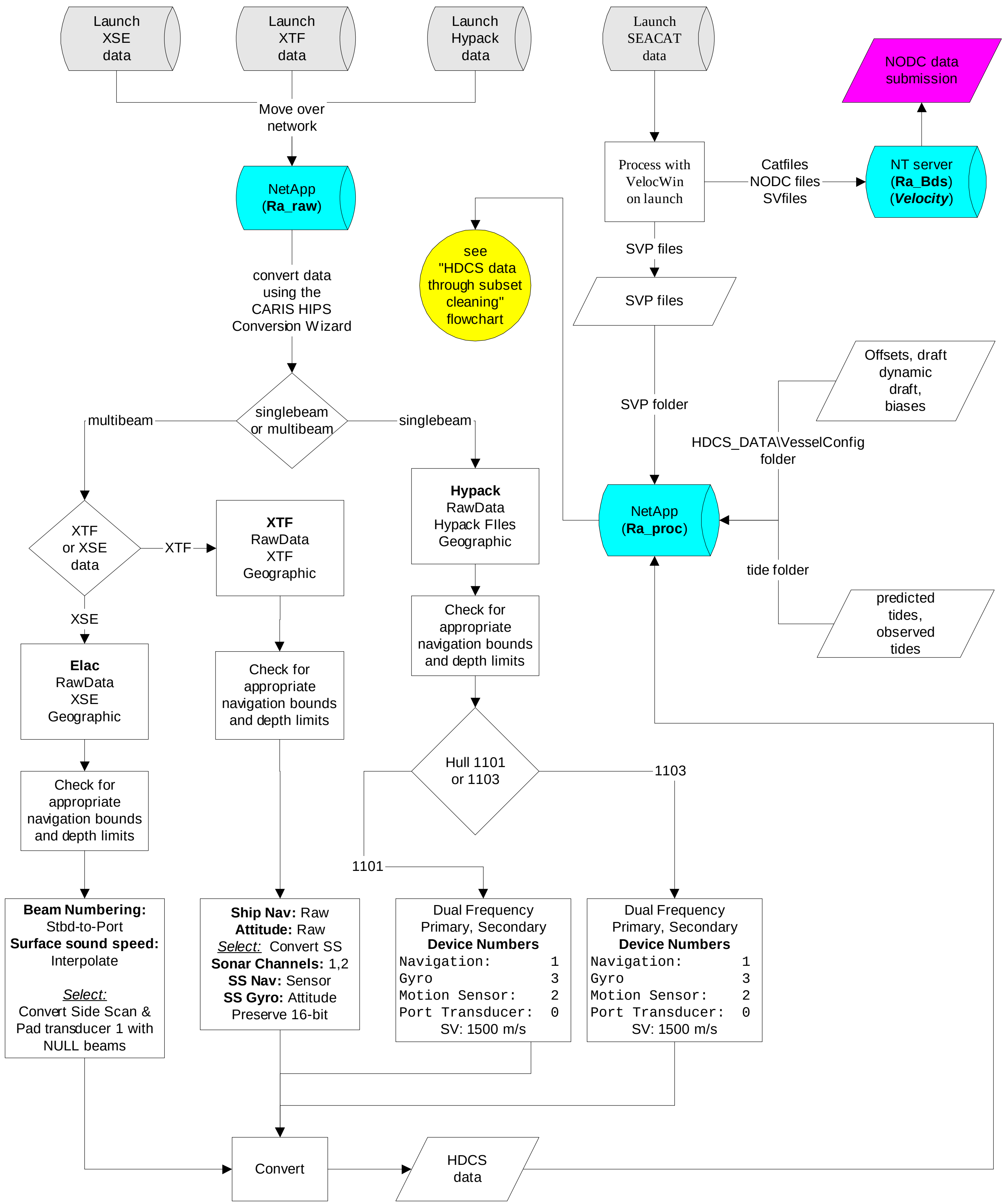
Field Operations Officer: ______________________________

Charles J. Yoos
Lieutenant, NOAA

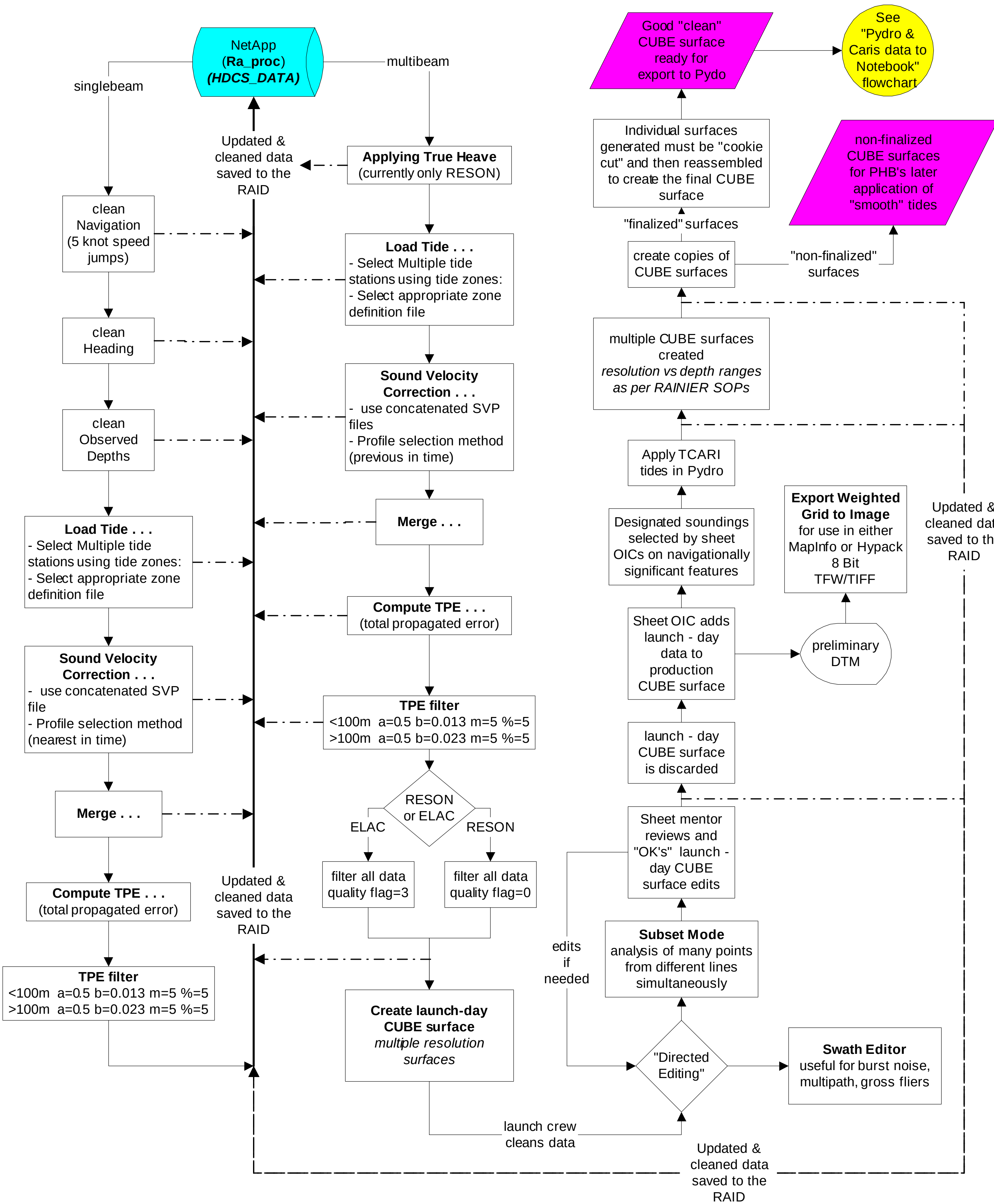
# APPENDIX I

## Data Processing Flow Diagrams

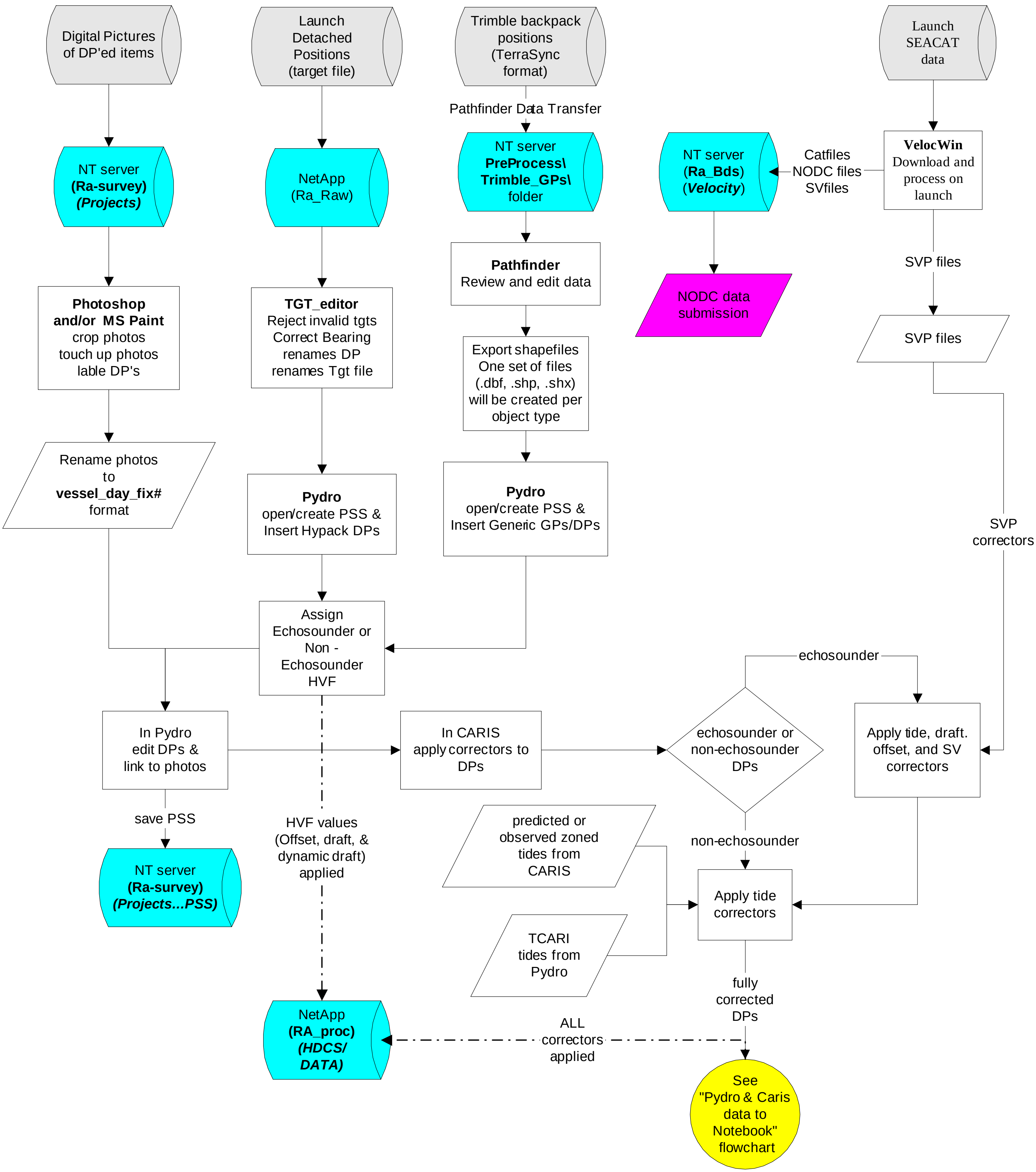
# Raw sounding data to HDCS



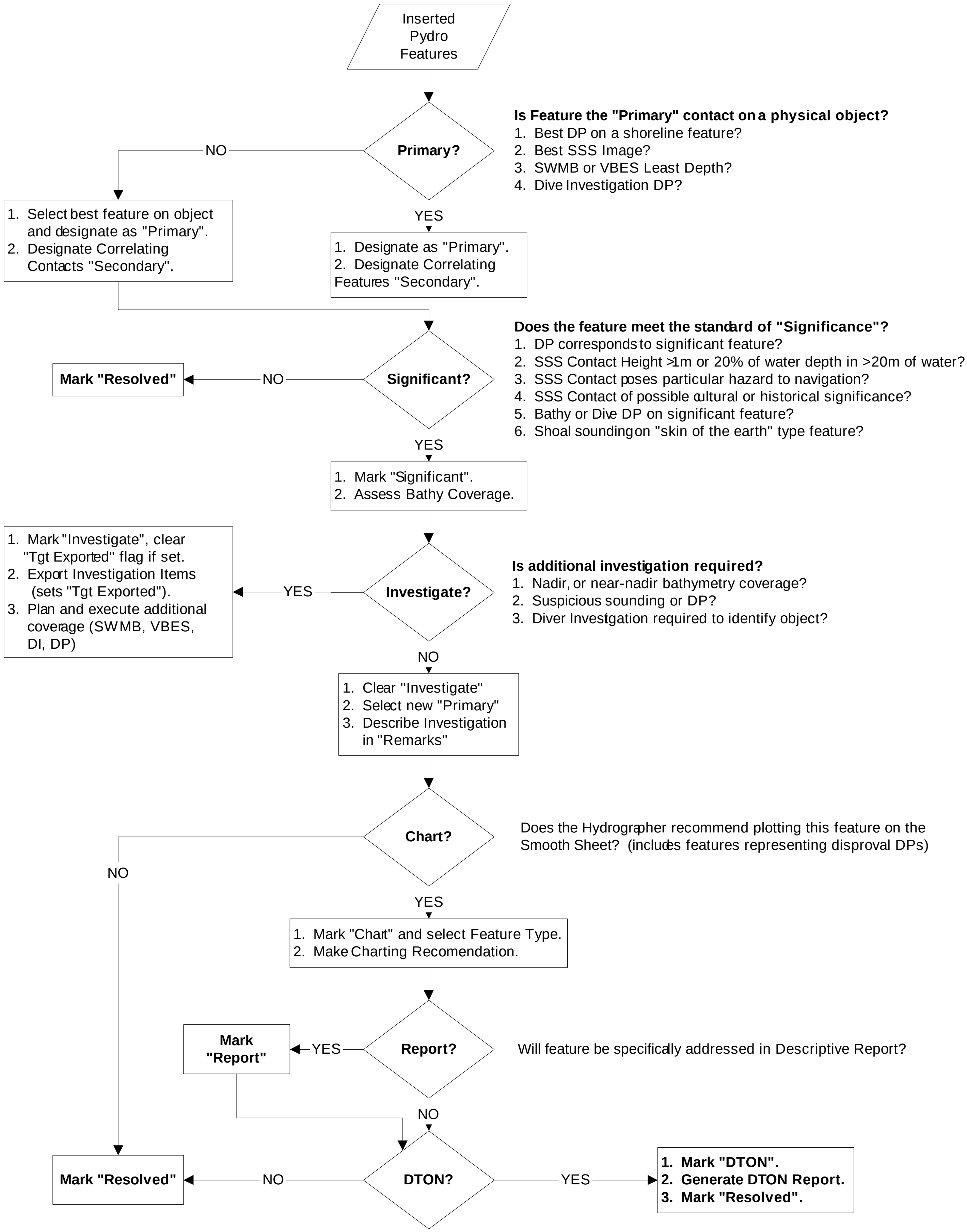
# HDCS data through subset cleaning



# Detached Position processing
# (Raw DP's to Pydro)



# Detached Position processing in Pydro



# Pydro & Caris data to Notebook