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

# Data Acquisition & Processing Report

*Type of Survey:* *External Source Data*

*Project No:* *OSD-DISCOVERY-16*

*Time Frame:* *Aug 2012 - Dec 2015*

LOCALITY

*State:* *Maryland*

*General Locality:* *Chesapeake Bay, Choptank River*

**2015**

*NOAA Chesapeake Bay Office*

LIBRARY & ARCHIVES

**DATE**:

# NOAA Chesapeake Bay Office
# Acoustic Seafloor Mapping
# Data Acquisition & Processing Report

**Type of Survey: Benthic Habitat and Hydrographic**

**Project No. CBO Field Season 2012-16**

**Time Frame: FY2012-FY16**

## Locality:

**Chesapeake Bay and associated tributaries**

**Chief Scientist:**

**John V. (Jay) Lazar, Jr.**

**Lead Hydrograher:**

**Andrew McGowan**

**Habitat Ecologist:**

**David G. Bruce**

# Data Acquisition & Processing Report

**Generic Template**

**2012-2016**

**NOAA R/V Potawaugh (F3002)**


**<u>Chief Scientist</u>**

**John V. (Jay) Lazar, Jr.**

**<u>Lead Hydrograher</u>**

**Andrew McGowan**

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## Appendices

## I. Objective

This project serves to acquire and produce critical baseline benthic habitat information including substrate and morphology for the purpose of monitoring native oyster restoration projects in Chesapeake Bay. This report will focus on the acquisition of bathymetry data collected from a multibeam echosounder. It may also include singlebeam data, sub bottom acoustic sonar profiles, as well as backscatter data from side scan sonar and multibeam. These data will inform restoration site selection, provide as-built conditions of construction projects, and ensure our ability to track the status of the restoration project over time. Data will be acquired to conform to IHO Order 1 accuracy standards. The strategy developed to map the survey area takes into account the minimum depths for permitting, general bathymetry, and project timelines.

## II. Area

The mission of the NOAA *RV Potawaugh* (F3002) is the exploration and mapping of shallow water habitats of Chesapeake Bay. Depth data has been acquired with a R2Sonic 2024 multibeam echosounder. The area of interest of the *RV Potawaugh* is the Chesapeake Bay and its surrounding tributaries.

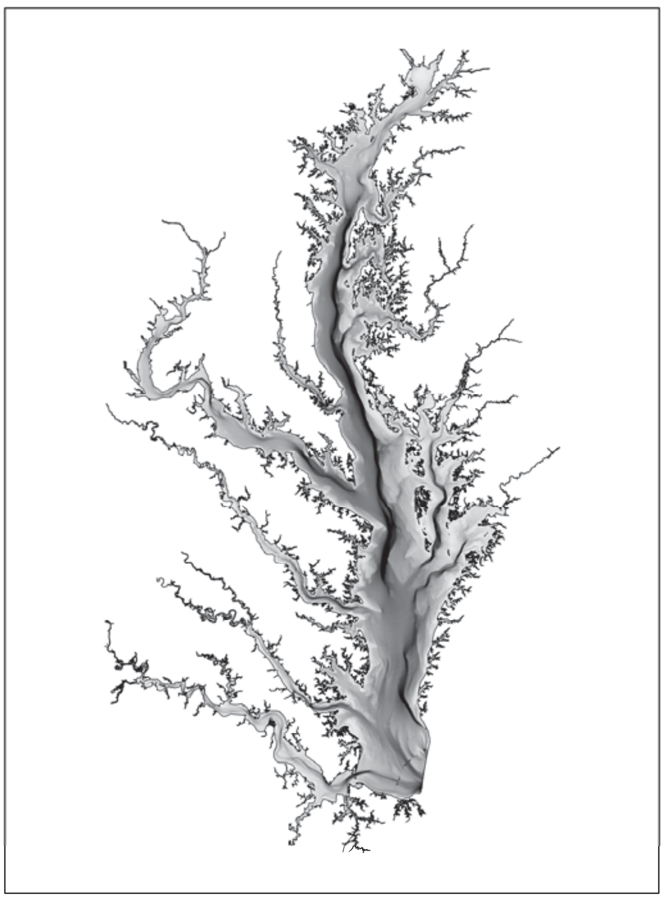


**Figure 1: Chesapeake Bay and Tributaries**

## III. Equipment

### Vessel

The National Oceanic and Atmospheric Administration Fisheries Research Vessel Potawaugh (F3002) measures 32 feet in length, has a beam of 10 feet and draws approximately 2 feet of water. The vessel is an Armstrong Marine, Inc. aluminum catamaran equipped with standard marine navigation electronics, a 7kw water cooled diesel generator, and twin 300hp Yamaha engines.

### Sonar System

A R2Sonic 2024 multibeam echosounder SN2007011 and topside SIM SN31381(shown to the left) was purchased in 2012 for multibeam data acquisition in the Chesapeake Bay. The R2Sonic 2024 has a dynamic frequency range of 200-400 kHz system with a rotatable 160° swath consisting of 256 individually formed electronically roll-stabilized 0.5° beams, a max range of 500 meters of water depth, and a maximum ping rate of 30Hz, depending on water depth. While conducting surveys the R2 system is operated at a frequency of 300 kHz. The swath angle is kept to a 140 degree equiangular beam transmit mode. Range, power, gain, and pulse width are tuned to the local survey area.

**Figure 2: R2 2024 sonar head**

### Vessel Positioning & Orientation

The Applanix POS/MV V5 (POS) is a vessel positioning and orientation system. The GPS aided Inertial Motion Unit (IMU) provides measurements of roll, pitch and heading that are all accurate to ± 0.02°. Heave measurements supplied by POS maintain an accuracy of at least 5% of the measured vertical displacement or ± 5cm for swell periods of 20 seconds or less. The accuracy and stability of measurements delivered by the system remain unaffected by vessel turns, changes of speed, wave-induced motion (sea state dependent), or other dynamic maneuvers. The IMU is located near the vessels center of motion; refer to Appendix D for the vessel offset diagram.

The POS obtains its positions from two dual frequency Trimble Zephyr GPS antennae. The two POS antennae are located across the cabin. An auxiliary Trimble DSM 232 DGPS system provided an RTCM differential data stream to the POS.

The POS system provides all the positioning and attitude data via Group 102, 111 and 113 via Ethernet to the Hypack Hysweep acquisition software. The POS Group 7 message is used to synchronize the acquisition PC clock. The POS heave bandwidth is set to 8.0 seconds with a dampening ration of .707. Roll, pitch, and heave positive sense are port up, bow up, and heave up respectively. The multipath is set to low, due to the proper placement of the two GPS antennae. There are also serial connections from the POS supplying TSS1 motion and the NMEA UTC message to the R2Sonic SIM. The UTC message is used to continually synchronize the R2Sonic SIM system clock.

**Sound Velocity**

The R2 Sonic 2024 echosounder is equipped with a real time sound velocity probe (Valport MiniSV) at the sonar head which interfaces with the topside unit. A Seabird Electronics SBE-19 Plus CTD is used for determining sound velocity throughout the water column for application in post processing of data. Sound velocity casts are taken approximately every four (4) hours or whenever there is a change in location or survey conditions. Sound velocity casts are processed with NOAA's Velocwin V8.96 or Pydro64 Velocipy v14.4 software and converted to CARIS format. Calibration reports from Seabird Electronics are documented in Appendix B.

**Acquisition System**

Hypack 2012, Hypack 2014, and Hypack 2015 provided the data acquisition platform for multibeam bathymetry and backscatter data collection. A coverage matrix is created for real-time verification of cover.

**Additional Sensors**

On occasion there is a need to collect additional acoustic sensor data from the following sensors: sidescan Sonar, sub-bottom profiler, and single beam sonar for acoustic classification. Acoustic interference or cross-talk with the multibeam does not occur with the placement and frequencies selected for all sensor acquisition.

## IV. Quality Control

The HIPS Conversion Wizard uses the .HSX format to convert the multibeam data into CARIS HDCS data files. During the conversion process no filters are applied to the data. The vessel configuration used for the data conversion is the R2_F3002.hvf or F3002_R2_2014.hvf files. This file includes the preliminary patch test results, the final patch test results, waterline and the Total Propagated Error (TPE) values (*.hvf & TPE Report, Appendix D). The data is projected to the North American Datum of 1983, Universal Transverse Mercator Zone 18, Northern Hemisphere (NAD83 UTM18N),

Data processing workflow consist of; Conversion of Hypack HSX files into Caris HDCS data format. Zoned verified tides are then applied to the data. Sound velocity profiles are applied to the data and selected by means of nearest in time, nearest in distance, previous in time or nearest in distance within time. This selection is made based on location and time of cast as it applies to the data in question. Ellipsoid referenced tides may also be computed using the Geoid height of the GPS antenna transformed to Mean Lower Low Water. This is conducted when a local zoned tide is not available or practical, when metrological events create a variance in typical water levels between the survey area and the tide gage, or when a secondary vertical check is desired to compare to the zoned tide value. Post processed navigation solutions from the Applanix Position Orientation System are exported into sbet binary files using POSPAC MMS software. Rms error data is are also extracted from the POSPAC MMS software and applied to the data along with the sbet navigation files. Total Propagated Uncertainty (TPE) is calculated using the vessel settings in the .hvf file used by Caris. Once TPE is calculate a CARIS Combined Uncertainty Bathymetric Editor (CUBE) Bathymetry Associated with Statistical Error (BASE) surface is created.

The Hips Subset Editor is the second phase of editing. After the creation of the CUBE BASE surfaces of depth, standard deviation and hypothesis count, Subset editing can be used to remove erroneous soundings and identify critical soundings not included in the BASE surface. It is also used to identifying potential tidal and motion artifacts. The verification and alignment of features from adjacent lines is used to confirm sensor offsets. CUBE BASE surfaces are created to illustrate adequate sonar coverage and to also identify systematic errors or artifacts within the data set. The BASE surfaces created from the merged and TPE calculated soundings are geo-referenced images of a weighted mean surface. The BASE surface uses a combination of range, uncertainty and swath angle weights to assign nodes depth values to create an image of the seabed surface. The BASE surface images are reviewed with multiple resolutions, sun angles, sun azimuths and vertical exaggerations. The BASE surface routine produced images representing depth, shoal-biased depth, deep-biased depth, mean depth, standard deviation, sounding density, and depth uncertainty.

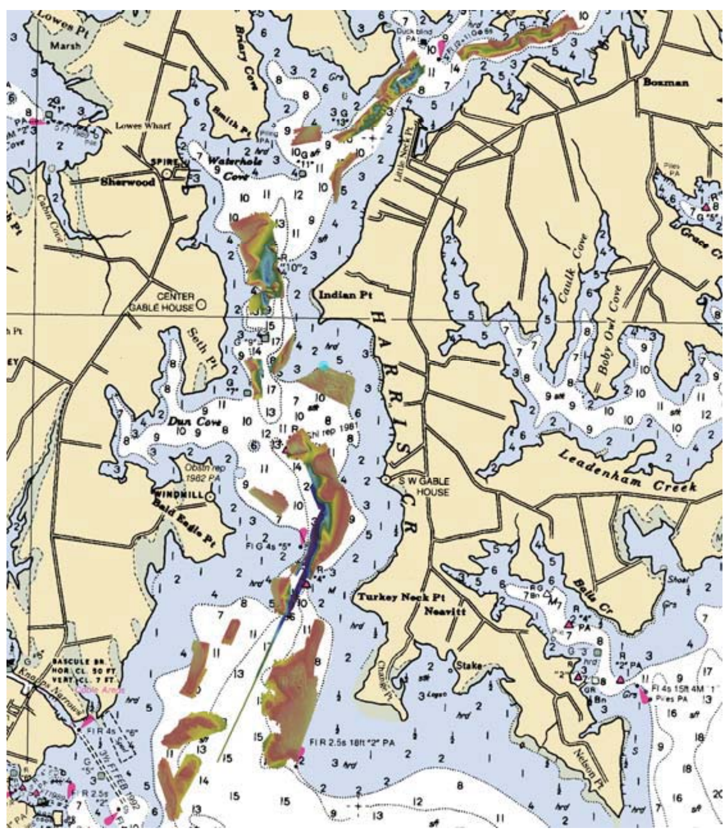



**Figure 2: Bathymetric surface of HACR2014 at 1m resolution.**

Following subset editing of the entire dataset, the Lead Hydrographer reviews and finalizes the dataset. This included the re-application of sound velocity profiles, application of critical soundings, application of zoned verified tides and updated sensor offset values, if needed, from the application of post-processed kinematic navigation data from the POS system.

Refer to Appendix E for a multibeam processing flow chart. The HIPS export wizard produces 24-bit sun-illuminated geo-referenced images of the BASE depth surfaces, and ASCII XYZ text exports at resolutions in accordance with the depth thresholds for the survey area. A final analysis is performed on the BASE depth surfaces with the Hips Quality Control Report and is discussed in the Assessment of IHO Compliance section.

## V. Corrections to Echo Soundings

### Instrument corrections

Leadline confidence checks were measured against the R2Sonic 2024 multibeam following the installation of the sonar and periodically thereafter. The purpose of these checks is to verify the system during static conditions by confirming that the digital depths being recorded reflect the actual depths. The leadline checks are performed on the starboard side of the multibeam system. The sonar's acquisition system logs data while the leadlines are performed. The CARIS swath editor is then used to verify the depth soundings. Soundings are queried approximately 0.1 meters to starboard of the nadir beam and verified to the leadline values. Instrument corrections have not been necessary without evidence of systematic error.

### Sensor Offsets

On February 08, 2012 an NGS survey team surveyed in the sensor offsets of RV Potawaugh. These offsets were entered into the Hypack acquisition software, POS/MV software and into the CARIS vessel configuration file in the appropriate areas. The offsets used for the sonar and positioning systems are documented in Appendix D. The survey report is found in Appendix G.

### Static and Dynamic Draft Corrections

Dynamic draft values have not been measured nor used for RV Potawaugh.

Static draft values were obtained from visual observations of the draft marks on the sonar pole mounted to the starboard side of RV Potawaugh. A leadline check was performed to verify the static draft calculations.

## System Alignment and Calibrations

System Alignment and calibration procedures are fully documented in Appendix F, the Multibeam Calibration Procedures & Patch Test Report. The initial patch test occurred March 1, 2012 in Chesapeake Bay near Bloody Point. The calculated patch test values for latency, roll, pitch and yaw were entered into the vessel configuration files. Subsequent patch tests occur if there is reason to believe a change has occurred or the opportunity presents itself. One such change occurred with the adjustment of the sonar a few cm outboard requiring a new support arm be fabricated. The offset was easily measured but the change in sensor alignment required a new patch test resulting in minor updates to the HVF.

## Tide Corrections

Zoned tide calculations are used where available in the Chesapeake Bay. Verified six-minute interval tide data are downloaded from a NOAA CO-OPS water level stations and converted into a text based .TID file. Zoned station offsets for tide height and time are applied using a CARIS tide zone definition file (ZDF) to account for distance between survey site and one or more tide stations in the vicinity. The zoned offset of the tide data from the station(s) is applied to the CARIS converted soundings in the post processing before the data are merged. It should be noted that the tidal error component could be significantly greater than estimated if a substantial meteorological event occurred during time of hydrography. In such cases ellipsoidal referenced heights are derived from the post processed positioning solutions exported by the POSPac software. Vdatum is used to convert reference geoid heights for the Chesapeake Bay to the MLLW datum and export as a text file. The MLLW water IMU height offset reference file is then input into CARIS using the GPS Tide Computation function and applied to the data when it is merged with GPS Tide selected at the time of merging.

# VI. Statement of Accuracy and Suitability for Charting

## Assessment of horizontal control

Positioning equipment and methods (Refer to OCS QMS Controlled Document titled *Ellipsoidally Referenced Surveys-Standard Operating Procedure*)

The horizontal datum for this project is the North American Datum of 1983 Universal Transverse Mercator Zone 18, Northern Hemisphere (NAD83 UTM18N). Differential GPS (DGPS) corrected positions from the POS/MV were supplied to all the acquisition systems. Each acquisition system has visual alarms to notify the operator if the DGPS fix is lost or if HDOP values of 4.0 are exceeded; none were observed. Differential beacon corrections were received from U.S. Coast Guard Continually Operating Reference Station (CORS) Annapolis, MD at a frequency of 301.0 kHz with the Trimble DSM 232 receiver.

Raw positioning and attitude data was recorded from the POSMV for post processed kinematic solutions. The Applanix Smart Base (ASB) virtual network was created using *Smart Select* for base station selection in POSPac MMS. The post processed data, navigation and error, for horizontal positioning was applied in CARIS.

Quality control

Position checks between two independent DGPS systems were not observed.

Statement of accuracy and compliance with HSSDM

Based on real-time tolerance monitoring, post processed kinematic solutions for navigation and motion, and seafloor feature alignment, the hydrographer considers the horizontal control adequate for the purposes of this survey.

**Assessment of vertical control**

Water level measuring equipment and methods

The Vertical Datum for this survey was Mean Lower-Low Water (MLLW). National Water Level Observation Network (NWLON) tide stations served as the primary source for vertical datum control across the survey season. Verified tides with final zoning were applied during post-processing of surveys where applicable. GPS Tides were used in some cases where the distance from the tide station proved too far for anomalous weather conditions experienced in the Chesapeake Bay.

Statement of accuracy and compliance with HSSDM

The hydrographer believes that the zoning of tide correctors from the primary tide station, the use of GPS Tides following OCS protocols and the hybrid solution for anomalous weather events is adequate for the purpose and location of the surveys.

**Assessment of sensors**

Ancillary sensors

Sound velocity profiles were acquired using the NOAA Chesapeake Bay Office's SeaBird Electronics (SBE) 19 Plus Conductivity, Temperature, and Depth (CTD) profiler (S/N 6398 and SN6913). Raw CTD data was processed using NOAA's Velocwin and velocipy software, which generated the sound velocity profiles required for real-time sounding corrections. Casts were recorded to the full depth of the area being surveyed.

The speed of sound through the water was determined by a minimum of one cast every four hours during multibeam acquisition. The primary CTD was checked against Surface velocities recorded by the Valeport Mini sound velocity profiler. Each unit had been calibrated prior to use for this survey; refer to Appendix B for the SBE calibration report.

**Assessment of Patch Test and Results**

The Hydrographer believes that the values of the latency, pitch, roll and gyro coupled with a thorough review of the patch test lines in Caris HIPS HDCS editor, adequately meet the alignment requirements for the survey.

**Assessment of Dynamic and Static Draft**

There are no dynamic draft values for RV Potawaugh.

Static draft values were obtained from visual observations of the draft marks on the starboard side of RV Potawaugh sonar pole. The Lead Hydrographer feels that the static draft corrections and the lack of dynamic draft corrections are adequate for this survey.

**Assessment of Horizontal and Vertical offsets**

Sensor Offsets

The Lead Hydrographer verified the sensor offset inputs for the POS/MV and the F3002_R2.hvf and F3002_R2_2014.hvf vessel configuration file. Refer to Appendix D for more information.

**Assessment of Sensor Calibrations**

Both the CTD and velocimeter underwent calibration prior to commencement of operations. Based on real-time tolerance monitoring and seafloor feature alignment the horizontal positions align well with other GIS raster datasets of imagery that confirm feature alignment. The offsets to these systems were accurately measured by an NGS Field Survey Party. The Lead Hydrographer checked and confirmed the measurements and offsets entered into software. The CTD values were confirmed by comparing the two units against each other at the surface and both received calibrations by the manufacturer within the previous 2 years. Patch tests are conducted whenever an adjustment to the sonar head is made or at the discretion of the hydrographer. Patch tests are initially processed in the field to derive preliminary offset values and reprocessed in the office with Post Processed Kinematic horizontal positions applied. Based on these results the Lead Hydrographer feels that all the systems are adequately calibrated for the purpose of these surveys.

**Assessment of Object Detection**

The 2024 ping rates are range dependent and set by the sonar operator. During acquisition the predominant sonar range was 30m resulting in a ping rate of 25hZ. The outer beam overlap is planned to achieve a 10% overlap in survey coverage. The goals of the survey are to meet object detection requirements that satisfy IHO Order 1 in waters shoaler than 30m.

Bottom Coverage and Line Spacing

The survey lines are generally planned parallel to the contours of the seafloor. Line spacing is determined by depth using 10% overlap with a 70° cutoff angle port and starboard. The line plan spacing does not exceed three times average water depth. Holiday lines are planned according to real time bathymetry mosaic surfaces created in the field and were surveyed to create as complete a surface as time permitted. The Lead Hydrographer determined that the bottom coverage and line spacing were considered adequate for the purposes of this survey.

<u>Vessel speed</u>

Survey operations are primarily conducted at a vessel speed of approximately 4-5 knots for the entire survey area with the goal of providing at least one sounding per 0.25m grid cell. Given a relatively high and constant ping rate, speeds are maintained to exceed the requirement of the NOAA Specs and Deliverables section 5.2.2: “The hydrographer shall ensure that the vessel speed is adjusted so than no less than 3.2 beam foot prints, center-to-center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction". Additionally, survey speeds are decreased while in shoal areas. In the opinion of the Lead Hydrographer, the vessel speeds and the sonar parameters used in this survey adequately ensonified the seafloor.

**Assessment of IHO Compliance and Quality Control Report**

Crosslines are occasionally surveyed. Where crosslines exist, CARIS generated Quality Control Reports are compiled for each survey area. This routine compares the crosslines for each project against the depth BASE surface. The results of the QC report are based on individual HDCS soundings associated with each beam from the crosslines, to a BASE surface created from the mainscheme data. In addition to comparing the crosslines to mainscheme data, the CARIS BASE surface QC report is also performed. This utility compares uncertainty values contained in the surface to IHO standards and created a compliance report. The survey goal is to meet and exceed IHO compliance for IHO order 1 for depths shoaler than 30m.

## VII. Summary of Submitted Data:

The following documentation and data will accompany this survey upon completion:

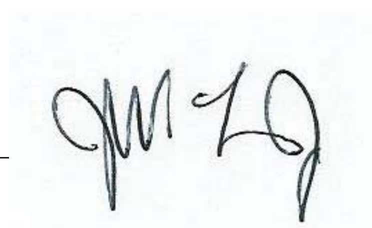
**Data**

- Raw multibeam sonar sounding files in HSX, RAW, R2S formats
- Raw POSPac files in *.000 format
- Processed multibeam sounding files in CARIS HDCS format
- Raw and processed sound velocity data files
- Processed sbet and rms files in *.OUT format
- Verified tides correctors
- Tidal zoning prepared by NOAA CO-OPS
- XYZ files
- Sun-Illuminated GeoTiffs
- CARIS Hydrographic Vessel Files (HVF)
- CARIS Session Files
- CARIS Fieldsheets

**Approval Sheet (Separate Signed Document Verifying DAPR information)**
**APPROVAL**

As Lead Hydrographer, I have ensured that standard field surveying and processing procedures were followed during this project in accordance with the Hydrographic Manual, Fourth Edition; Hydrographic Survey Guidelines; Field Procedures Manual, and the NOS Hydrographic Surveys Specifications and Deliverables Manual.

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

Approved and Forwarded: ___  LAZAR.JOHN.V.JR.1383925629 ______

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John V. Lazar Jr.
ACSM Hydographer #223

# APPENDIX A:

## Hydrographic Hardware/Software Inventory

Hydrographic Systems Inventory  CY2012-2015 Field Seasons

| Equipment Type | Manufacturer | Model | Serial # | Firmware |
|---|---|---|---|---|
| Transducer | **R2Sonic** | **2024** | **2007011** | **June 27, 2014** |
| Transceiver Unit | **R2Sonic** | | **31381** | **June 27, 2014** |
| Inertial GPS PCS | **Applanix** | **POS/MV V5** | **3631** | **V5.01 – V7.6** |
| IMU | **Applanix** | **IMU-17** | **N/A** | **V5.01** |
| DGPS | **Trimble** | **DSM 232** | **225120493** | **N/A** |
| Acquisition PC | **N/A** | **N/A** | **N/A** | **N/A** |
| Surface SVP | **Valeport** | **Mini** | **98352** | **1.11** |
| Profile SVP | **SBE** | **SBE-19plus** | **6398** | **N/A** |
| Profile SVP | **SBE** | **SBE-19plus** | **6913** | **N/A** |

Hydrographic Software CY2012 Field Season

| Equipment Type | Manufacturer | Model | Software Version |
|---|---|---|---|
| Acquisition | **Hypack** | **Survey** | **2012-2015** |
| Acquisition | **Hypack** | **Hysweep.exe** | **10.0.7.0-15.0.12.0** |
| Acquisition | **Hypack** | **Swpware.exe** | **10.0.7.0-15.0.0.0** |
| Acquisition | **Hypack** | **posmv.dll** | **10.0.5.4-15.0.7.4** |
| Acquisition | **Applanix** | **POS Controller** | **5.1.0.2** |
| Processing | **NOAA** | **Velociwin** | **8.96** |
| Processing | **NOAA** | **Velocipy** | **14.4** |
| Processing | **CARIS** | **HIPS** | **7. 1.2 SP2-9.019** |
| Processing | **Applanix** | **POSPAC MMS** | **6.1 SP1** |

# APPENDIX B:

## SBE Calibration Reports

**SBE-19plus** (SN6398)
June 08, 2011 Report in PDF, sent upon request.
February, 2014 Report in PDF, sent upon request.

**SBE-19plus** (SN6313)
October, 2011 Report in PDF, sent upon requrest.
August 19, 2015 Report in PDF, sent upon request.

## APPENDIX C:

### Vessel Configurations & TPE Report

# Total Propagated Error (TPE) Report

RV Potawaugh

Caris HIPS has an error model that derives from a sounding's source errors the total propagated error (TPE) for that sounding. The sources of the estimates of the various errors vary from manufacturers' specifications, to theoretical values, to field tested empirical observations. The error estimates (one sigma) are entered into the TPE sensor section of an HVF.

Below is a table listing various source errors and their estimate, followed by a detailed discussion describing each error estimate.

| Error Source | Error Estimate |
|---|---|
| *Heave % Amplitude* | 5.0 |
| *Heave* | 0.05 |
| *Gyro* | 0.02 |
| *Roll* | 0.02 |
| *Pitch* | 0.02 |
| *Navigation* | 0.5 |
| *Timing Transducer* | 0.001 |
| *Navigation Timing* | 0.001 |
| *Gyro Timing* | 0.001 |
| *Heave Timing* | 0.001 |
| *Pitch Timing* | 0.001 |
| *Roll Timing* | 0.001 |
| *Sound Velocity Measured* | 0.00 |
| *Surface* | 0.00 |
| *Tide Measured* | 0.00 |
| *Tide Zoning* | 0.20 |
| *Offset X* | 0.005 |
| *Offset Y* | 0.005 |
| *Offset Z* | 0.005 |
| *Vessel Speed* | 0.01 |
| *Loading* | 0.02 |
| *Draft* | 0.020 |
| *Delta Draft* | 0.02 |

## Detailed Discussion of Error Estimates

**Heave % Amplitude**

Error: 5.0

Definition: *Heave % Amplitude* is an additional heave standard deviation component that is the percentage of the instantaneous heave.

Discussion: See *Heave* discussion below.

**Heave**

Error: 0.05

Definition: *Heave* is the measurement for standard deviation of the heave data in meters.

Discussion: The POS/MV heave error is given as 0.05 meters + 5% of heave; however, the Caris error model implementation uses *Heave* or *Heave % Amplitude*, whichever is greater (see *Heave* discussion below). Thus a value of 0.06 for *Heave* is used as a compromise

**Gyro**

Error: 0.02

Definition: *Gyro* is the measurement standard deviation of the heading data in degrees.

Discussion: *Gyro* is based on POS/MV manufacturer specifications

**Roll**

Error: 0.02

Definition: *Roll* is the measurement standard deviation of the roll data in degrees.

Discussion: *Roll* is based on POS/MV manufacturer specifications.

**Pitch**

Error: 0.02

Definition: *Gyro* is the measurement standard deviation of the heading data in degrees.

Discussion: *Pitch* is based on POS/MV manufacturer specifications.

**Navigation**

Error: 0.5

Definition: *Navigation* is the standard deviation associated with the measurement of positions for the vessel in meters.

Discussion: *Navigation* is based on POSPAC processed position errors.

**Timing Transducer**

Error: 0.001

Definition: *Timing Transducer* is the standard deviation of transducer time stamp measurements.

Discussion: *Timing Transducer* is based on POS/MV manufacturer specifications.

**Navigation Timing**

Error: 0.001

Definition: *Navigation Timing* is the standard deviation of navigation time stamp measurements.

Discussion: *Navigation Timing* is based on POS/MV manufacturer specifications.

**Gyro Timing**

Error: 0.001

Definition: *Gyro Timing* is the standard deviation of gyro time stamp measurements.

Discussion: *Gyro Timing* is based on POS/MV manufacturer specifications.

**Heave Timing**

Error: 0.001

Definition: *Heave Timing* is the standard deviation of heave time stamp measurements.

Discussion: *Heave Timing* is based on POS/MV manufacturer specifications.

**Pitch Timing**

Error: 0.001

Definition: *Pitch Timing* is the standard deviation of pitch time stamp measurements.

Discussion: *Pitch Timing* is based on POS/MV manufacturer specifications.

**Roll Timing**

Error: 0.001

Definition: *Roll Timing* is the standard deviation of roll time stamp measurements.

Discussion: *Roll Timing* is based on POS/MV manufacturer specifications.

**Sound Velocity Measured**

Error: 0.05

Definition: *Sound Velocity Measured* is the standard deviation of the measurement of sound velocity readings in meters/second.

Discussion: *Sound Velocity Measured* is based on Seabird manufacturer specifications.

**Surface**

Error: 0.04

Definition: *Surface* is the standard deviation of the measurement

of surface sound speed readings in meters/second.
Discussion: *Sound Velocity Measured* is based on Valeport manufacturer specifications.

**Tide Measured**
Error: 0.005
Definition: *Tide Measured* is the standard deviation of the measured tide values in meters.
Discussion: *Tide Measured* is based on CO-OPS calculations.

**Tide Zoning**
Error: 0.20
Definition: *Tide Zoning* is the standard deviation of the tide values associated with zoning in meters.
Discussion: *Tide Zoning* is based on general CO-OPS calculations.

**Offset X**
Error: 0.005
Definition: *Offset X* is the standard deviation of the measured X offsets of the vessel.
Discussion: *Offset X* is the accuracy limit of the total station survey method used to survey the vessel.

**Offset Y**
Error: 0.005
Definition: *Offset Y* is the standard deviation of the measured X offsets of the vessel.
Discussion: *Offset Y* is the accuracy limit of the total station survey method used to survey the vessel.

**Offset Z**
Error: 0.005
Definition: *Offset Z* is the standard deviation of the measured X offsets of the vessel.
Discussion: *Offset Z* is the accuracy limit of the total station survey method used to survey the vessel.

**Vessel Speed**
Error: 0.01
Definition: *Vessel Speed* is the standard deviation for the vessel speed measurements in meters/second.
Discussion: *Vessel Speed* is based on POS/MV manufacturer specifications.

**Loading**
Error: 0
Definition: *Loading* is the measurement standard deviation of the

vertical changes during the survey because of fuel consumption, etc. *Loading* corresponds to the Caris waterline measurement error.

Discussion: *Loading* is not currently used. Further investigation is required.

**Draft**

Error: 0.02

Definition: *Draft* is the standard deviation of the vessel draft measurements in meters.

Discussion: *Draft* is the accuracy limit of the draft measuring method.

**Delta Draft**

Error: 0.02

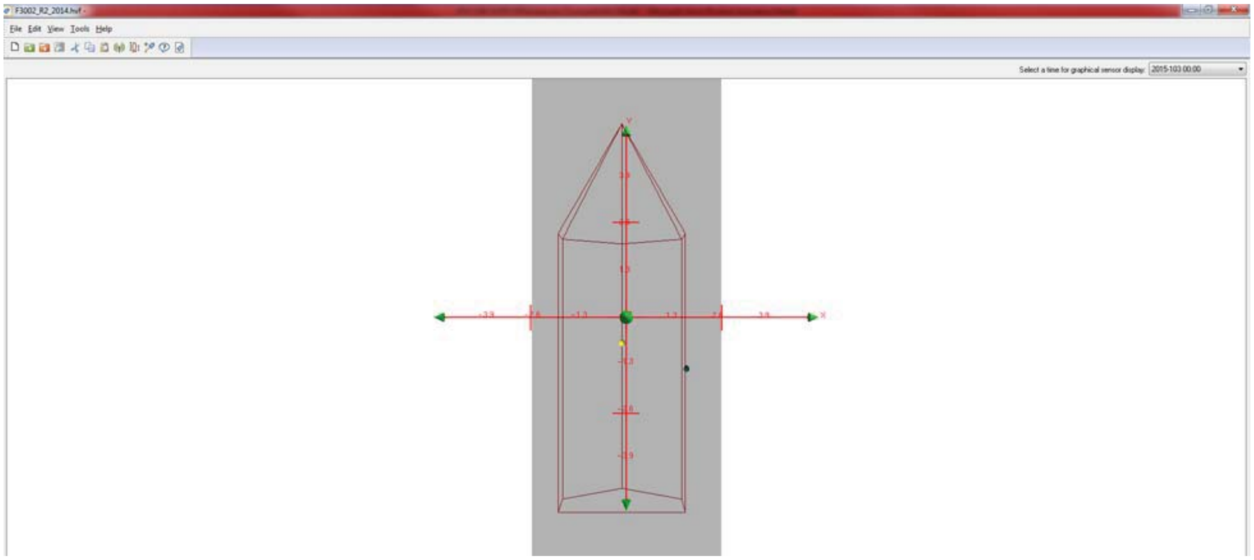
Definition: *Delta Draft* is the standard deviation of the dynamic vessel draft measurements in meters.

Discussion: *Delta Draft* is the accuracy limit of the change in draft observed aboard the vessel.

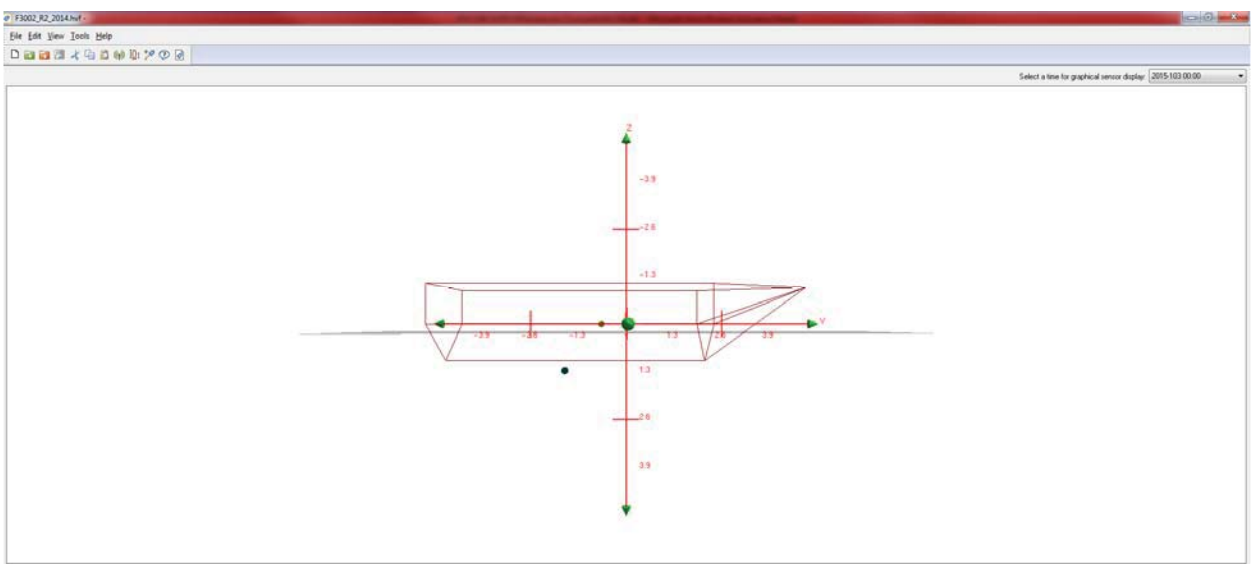
## APPENDIX D:

## NOAA RV F3002 Offset Diagram

**Plan View:**



**Side View:**



Sensor Offsets:
Vessel Name: F3002_R2.hvf
Vessel created: February 11, 2013

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2012-109 00:00

Comments: Pre-PosPac offsets
Time Correction(s) 0.000

Transduer #1:
-------------
Pitch Offset: 2.100
Roll Offset: 0.400
Azimuth Offset:1.000

DeltaX:1.826
DeltaY:-0.803
DeltaZ: 1.265

Manufacturer:
Model: r2s2024b
Serial Number:

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2012-116 00:00

Comments: Pre-POSPac offsets- reduced draft
Time Correction(s) 0.000

Transduer #1:
-------------
Pitch Offset: 0.700
Roll Offset: 0.450
Azimuth Offset:2.900

DeltaX:1.826
DeltaY:-0.803
DeltaZ: 1.187

Manufacturer:
Model: r2s2024b
Serial Number:

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2012-124 00:00

Comments: Post-POSPac offsets
Time Correction(s) 0.000

Transduer #1:
-------------
Pitch Offset: -0.370
Roll Offset: 0.450
Azimuth Offset:2.550

DeltaX: 1.826
DeltaY: -0.803
DeltaZ: 1.187

Manufacturer:
Model: r2s2024a
Serial Number:

Depth Sensor:

Sensor Class: Swath
Time Stamp: 2012-139 00:00

Comments: Support Arm modified and replaced; angle offsets determined later in dn339 patch w/POSPac data
Time Correction(s) 0.000

Transduer #1:
-------------
Pitch Offset: -0.410
Roll Offset: 0.420
Azimuth Offset:2.600

DeltaX: 1.846
DeltaY: -0.803
DeltaZ: 1.187

Manufacturer: R2 Sonics 2024 200kHz
Model: Unknown
Serial Number:

---

Navigation Sensor:

Time Stamp: 2012-109 00:00

Comments:
Time Correction(s) 0.000
DeltaX: 0.000

DeltaY: 0.000
DeltaZ: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

---

Gyro Sensor:

Time Stamp: 2012-109 00:00

Comments:
Time Correction(s) 0.000

---

Heave Sensor:

Time Stamp: 2012-109 00:00

Comments:
Apply Yes
Time Correction(s) 0.000
DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000
Offset: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

---

Pitch Sensor:

Time Stamp: 2012-109 00:00

Comments:
Apply Yes
Time Correction(s) 0.000
Pitch offset: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

---

Roll Sensor:

Time Stamp: 2012-109 00:00

Comments:
Apply Yes
Time Correction(s) 0.000
Roll offset: 0.000

Manufacturer: (null)
Model: (null)
Serial Number: (null)

---

Draft Sensor:

Time Stamp: 2012-109 00:00

Apply Yes
Comments:
Time Correction(s) 0.000

---

TPU

Time Stamp: 2012-116 00:00

Comments:
Offsets

Motion sensing unit to the transducer 1
X Head 1 1.826
Y Head 1 -0.803
Z Head 1 1.187
Motion sensing unit to the transducer 2
X Head 2 0.000
Y Head 2 0.000
Z Head 2 0.000
Navigation antenna to the transducer 1
X Head 1 1.826
Y Head 1 -0.803
Z Head 1 1.187
Navigation antenna to the transducer 2
X Head 2 0.000
Y Head 2 0.000
Z Head 2 0.000

Roll offset of transducer number 1 0.450
Roll offset of transducer number 2 0.000

Heave Error: 0.050 or 5.000" of heave amplitude.
Measurement errors: 0.005
Motion sensing unit alignment errors
Gyro:0.000 Pitch:0.000 Roll:0.000
Gyro measurement error: 0.020

Roll measurement error: 0.020
Pitch measurement error: 0.020
Navigation measurement error: 0.500
Transducer timing error: 0.001
Navigation timing error: 0.001
Gyro timing error: 0.001
Heave timing error: 0.001
PitchTimingStdDev: 0.001
Roll timing error: 0.001
Sound Velocity speed measurement error: 0.000
Surface sound speed measurement error: 0.000
Tide measurement error: 0.000
Tide zoning error: 0.000
Speed over ground measurement error: 0.010
Dynamic loading measurement error: 0.000
Static draft measurement error: 0.020
Delta draft measurement error: 0.020
StDev Comment: (null)

---

Svp Sensor:

Time Stamp: 2012-109 00:00

Comments:
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 1.826
DeltaY: -0.803
DeltaZ: 1.265

SVP #2:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Time Stamp: 2012-116 00:00

Comments:
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 1.826
DeltaY: -0.803
DeltaZ: 1.187

SVP #2:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Time Stamp: 2012-124 00:00

Comments:
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 1.826
DeltaY: -0.803
DeltaZ: 1.187

SVP #2:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Time Stamp: 2012-139 00:00

Comments:

Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 1.846
DeltaY: -0.803
DeltaZ: 1.187

SVP #2:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

Time Stamp: 2012-305 00:00

Comments: (null)
Time Correction(s) 0.000

Svp #1:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 1.846
DeltaY: -0.803
DeltaZ: 1.187

SVP #2:
-------------
Pitch Offset: 0.000
Roll Offset: 0.000
Azimuth Offset:0.000

DeltaX: 0.000
DeltaY: 0.000
DeltaZ: 0.000

WaterLine:

Time Stamp: 2012-109 00:00

Comments: measured during initial patch test
Apply Yes
WaterLine 0.265

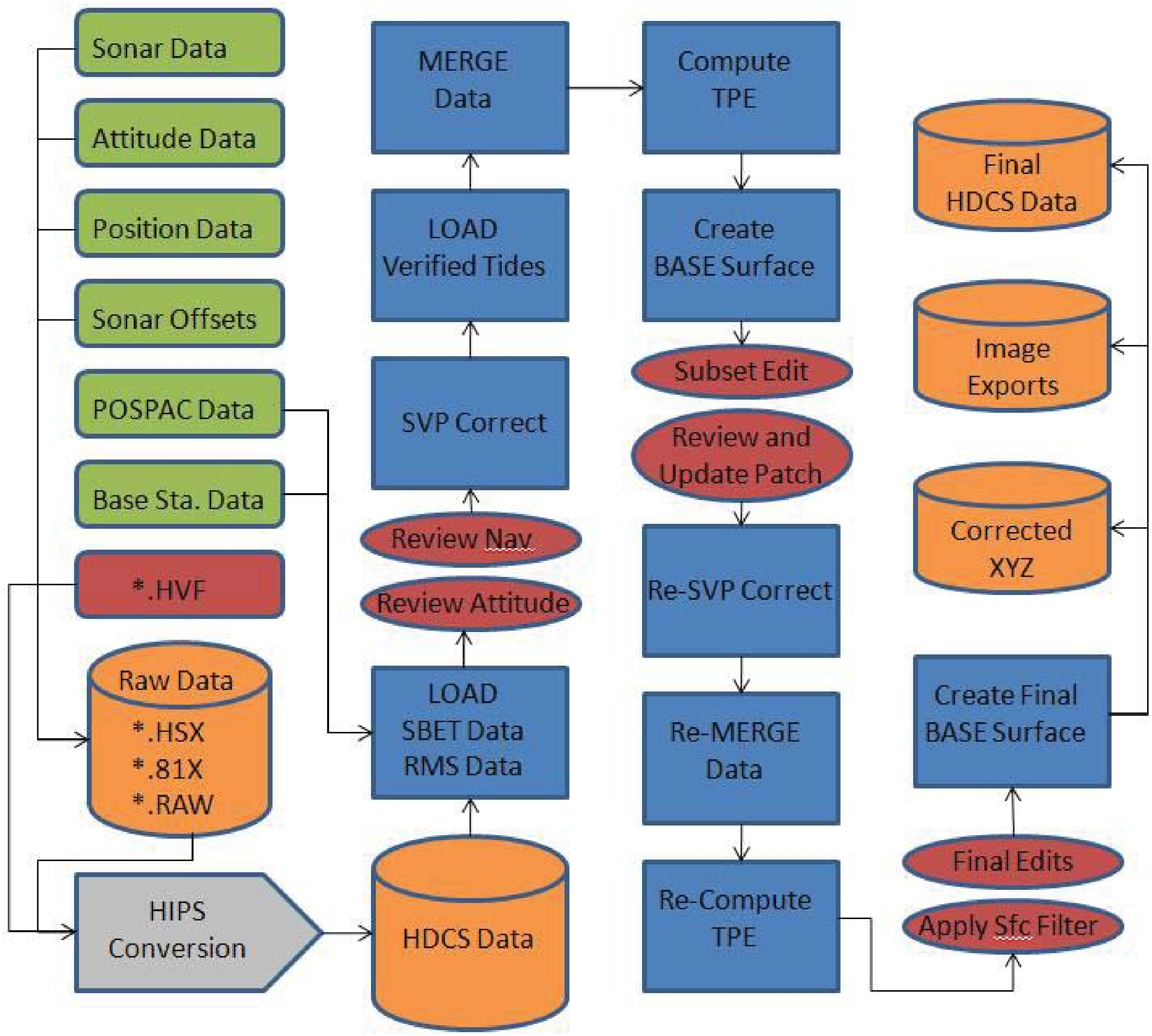
Time Stamp: 2012-305 00:00

Comments: survey draft measurement
Apply Yes
WaterLine 0.225

---

## APPENDIX E:

## CARIS Processing Flow Chart



# APPENDIX F:

## Multibeam Calibration Procedures & Patch Test Reports

**Calibration Date: May 19, 2015**

| | |
|---|---|
| Ship | NOAA RV Potawaugh |
| Vessel | NOAA RV Potawaugh |
| Echosounder System | R2Sonic 2024 |
| Positioning System | POS/MV Model V5 |
| Attitude System | POS/MV Model V5 |

Calibration type:

| | | | |
|---|---|---|---|
| Annual | | Full | |
| Installation | | Limited/Verification | X |
| System change | | | |
| Periodic/QC | X | | |
| Other: | | | |

The following calibration report documents procedures used to measure and adjust sensor biases and offsets for multibeam echosounder systems. Calibration must be conducted A) prior to CY survey data acquisition B) after installation of echosounder, position and vessel attitude equipment C) after changes to equipment installation or acquisition systems D) whenever the Hydrographer suspects incorrect calibration results. The Hydrographer shall periodically demonstrate that calibration correctors are valid for appropriate vessels and that data quality meets survey requirements. In the event the Hydrographer determines these correctors are no longer valid, or any part of the echosounder system configuration is changed or damaged, the Hydrographer must conduct new system calibrations.

Multibeam echosounder calibrations must be designed carefully and individually in consideration of systems, vessel, location, environmental conditions and survey requirements. The calibration procedure should determine or verify system offsets and calibration correctors (residual system biases) for draft (static and dynamic), horizontal position control (DGPS), navigation timing error, heading, roll, and pitch. Standard calibration patch test procedures are described in *Field Procedures for the Calibration of Multibeam Echo-sounding Systems*, by André Godin (Documented in Chapter 17 of the Caris HIPS/SIPS 5.3 User Manual, 2003). Additional information is provided in *POS/MV Model 320 Ver 3 System Manual* (10/2003), Appendix F, Patch Test, and the NOAA Field Procedures Manual (FPM, 2003). **The patch test method only corrects very basic alignment biases**. These procedures are used to measure static navigation timing error, transducer pitch offset, transducer roll offset, and transducer azimuth offset (yaw). Dynamic and reference frame biases can be investigated using a reference surface.

## Pre-calibration Survey Information

### Reference Frame Survey

(IMU, sensor, GPS antenna offsets and rotation with respect to vessel reference frame)

Vessel reference frame defined with respect to:

[x] IMU Reference [ ] Position

Reference to IMU Lever Arm

| X(m) | Y(m) | Z(m) |
|---|---|---|
| 0.0 | 0.0 | 0.0 |
| | | |

IMU frame w.r.t vessel reference frame

| X(deg) | Y(deg) | Z(deg) |
|---|---|---|
| 0.0 | 0.0 | 0.0 |

Reference to Sensor Lever Arm

| X(m) | Y(m) | Z(m) |
|---|---|---|
| 1.846 | -0.803 | 1.105 |

[ ] Measurements verified for this calibration.

[X] Reference Vessel Offset Appendix Drawing and table attached.

[X] Drawing and table included with project report/DAPR: 2015-NCBO-F3002-MB-DAPR

### Position/Motion Sensor Calibration (for POS/MV model Wavemaster)

Calibration date: February 8th 2012

Reference to starboard/primary GPS Lever Arm

| X(m) | Y(m) | Z(m) |
|---|---|---|
| -0.096 | 1.052 | -2.570 |

Heave Settings: Bandwidth 8.00 Damping Period .707

Reference to Center of Rotation Lever Arm

| X(m) | Y(m) | Z(m) |
|---|---|---|
| 0.0 | 0.0 | 0.0 |

Firmware version 5.01 was used for the entire survey.

## Calibration Survey Information

A routine patch test was performed for the R2 2024 sonar system after the vessel was moved to the Potomac River Mouth survey area. The CARIS calibration routine was used to determine the sensor mounting angle offsets.

**Calibration Lines**

| Line | Direction | Speed (knots) | Bias Measured |
|---|---|---|---|
| **2015_1391527_1** | **W** | **4.8** | **Y1** |
| **2015_1391530_2** | **E** | **4.4** | **P1, R1** |
| **2015_1391532_2** | **E** | **4.8** | **P2, R2, Y2** |

## Sound Velocity Correction

Sound velocity through water (SV) is measured prior to survey operations in the immediate vicinity of the calibration site. SV observations are conducted as often as necessary to monitor changing conditions. SV measurements are measured at the transducer face in real time and monitored for any changed in surface SV during the calibration. A new cast is taken if any significant SV fluctuations are observed during the calibration process.

**Sound Velocity Measurements**

| Cast | Time (UTC) | Depth(m) | LAT | LONG |
|---|---|---|---|---|
| 2015_139_121744 | 12:17:00 | 9 | 38 04 33 N | 076 24 15 W |

## Tide Correction

Zerotide applied

**Approximate distance of gauge from calibration site:** NA

**Water level corrections applied:**

☐ Predicted
☐ Preliminary
☐ Zoned

Verified ☐

## Data Acquisition and Processing Guidelines

Initially, calibration measurement offsets were set to zero in the vessel configuration files. Static and dynamic draft offsets, inertial measurement unit (IMU) lever arm offsets, and vessel reference frame offsets were entered in appropriate software applications prior to bias analysis. Minimal cleaning was performed to eliminate gross flyers from sounding data.

**Navigation Timing Error (NTE)**

Measure NTE correction through examination of a profile of the center beams from lines run in the same direction at maximum and minimum vessel speeds. NTE is best observed in shallow water.

**Transducer Pitch Offset (TPO)**

Apply NTE correction. Measure TPO correction through examination of a profile of the center beams from lines run up and down a bounded slope or across a conspicuous feature. Acquire data on lines oriented in opposite directions, at the same vessel speed. TPO is best observed in deep water.

**Transducer Roll Offset (TRO)**

Apply NTE and TPO corrections. Measure the TRO correction through examination of roll on the outer beams across parallel overlapping lines. TRO is best observed over flat terrain in deep water.

**Transducer Azimuth Offset (TAO or yaw)**

Apply NTE, TPO and TRO corrections. Measure TAO correction through examination of a conspicuous topographic feature observed on the outer beams of lines run in the same direction.

**Final Patch Test Results and Correctors**

| Evaluator | NTE (sec) | TPO (deg) | TAO (deg) | TRO (deg) |
|---|---|---|---|---|
| John V. Lazar Jr | 0.0 | -0.410 | 1.600 | 0.420 |

[X] Caris ISIS [ ]

[ ] Other ____________________

## Caris Vessel Configuration File

Name: R2_F3002.hvf

Version: 9.0.21

New [ ] Appended values with time tag [x]

Evaluator: John V. Lazar Jr

## Additional patch test calculated transducer alignments

| F3002 R2 2024 Transducer positioning | Y | X | Z | Roll | Pitch | Heading | Date |
|---|---|---|---|---|---|---|---|
| R2 2024 (HVF convention Y,X,Z) | **-0.803** | **1.826** | **1.187** | **0.42** | **-0.41** | **2.600** | **4/24/2012** |
| R2 2024 (HVF convention Y,X,Z) | **-0.803** | **1.851** | **1.187** | **0.42** | **-0.41** | **2.600** | **5/18/2012** |
| R2 2024 (HVF convention Y,X,Z) | **-0.803** | **1.851** | **0.971** | **0.42** | **-0.41** | **2.440** | **4/15/2014** |
| R2 2024 (HVF convention Y,X,Z) | **-0.803** | **1.851** | **1.107** | **0.42** | **-0.41** | **2.600** | **9/2/2014** |
| R2 2024 (HVF convention Y,X,Z) | **-0.803** | **1.851** | **1.105** | **0.42** | **-0.41** | **1.600** | **4/13/2015** |

**APPENDIX G:**
NGS F3002 Sensor Offset Survey

# U.S. Department of Commerce

## National Oceanic & Atmospheric Administration

National Ocean Service National
Geodetic Survey Field
Operations Branch

Kevin Jordan
February, 2012

NOAA Boat – F 3002

IMU and Component Survey PURPOSE

The intention of this survey was to accurately position the Inertial Measuring Unit (IMU) and various other components onboard the NOAA boat F 3002.

PROJECT DETAILS

This survey was conducted on February 8, 2012 at the David Taylor Research Center on the U.S. Naval Academy Base in Annapolis, MD. The boat was towed by trailer to an open area for the ease of survey. There were no existing bench marks for reconnaissance. New bench marks were set for future recovery.

INSTRUMENTATION

The TOPCON GPT 3000 Series Total Station was used to make all measurements.

A SECO 25 mm Mini Prism System configured to have a zero mm offset was used as target sighting and distance measurements.

SOFTWARE AND DATA COLLECTION

TDS Survey Pro Ver. 4.7.1

ForeSight DXM Ver. 3.2.2 was used for post processing. PERSONNEL

Kevin Jordan NOAA/NOS/NGS/Field Operations Branch 757-441-3603 Joseph Kordosky

NOAA/NOS/NGS/Field Operations Branch 757-441-6265

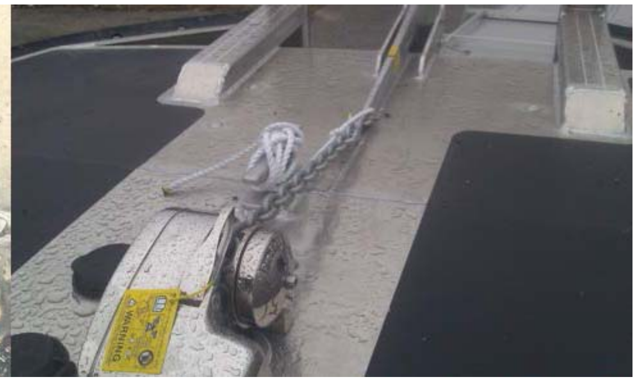
NOAA Boat – F 3002

IMU and Component Survey

## SURVEY PROCEDURES

# New Stations

Bow



Starboard Forward



Port Forward


Port Aft



Multi Beam Reference Point



IMU Offset – No Photo – This station was stamped, but not labeled. Reference mark located forward and slightly to the right of the currently installed IMU on the center beam that runs along the center of the boat.

### Establishing the Centerline

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

A temporary centerline mark (TCL) was established to align horizontally with the Bow Bench Mark. This was performed by measuring port to starboard at the stern of the boat and placing a temporary ink mark at the center. The theodolite was setup on this point and initialized on the Bow Bench Mark with an azimuth of 0° 00' 00". The theodolite was turned to an azimuth of 180° 00' 00" and a temporary station was set off the boat on solid ground and labeled TP1.

Setup 1:
Observing from TP1 and initializing on the temporary centerline discussed above, we collected points: TP2 (Originally the temporary centerline) IMU Offset

IMU
Side Scan Tow Point
Starboard GPS (ARP) Port
GPS (ARP) DGPS (ARP)
Multi Beam Reference Point Multi Beam
Reference Point Top

Multi Beam Reference Point Bottom

TP3 Set Port Side of the boat on solid ground
A positional check was made to TP2 at the end of the setup and agreed X = 0.0 m, Y = 0.001 m, and X = -0.001 m.

Setup 2:
Observing from TP3 and initializing on TP1 we collected points: Port Aft Bench Mark
Star Aft Bench Mark Bow
Bench Mark
Starboard Forward Bench Mark Port
Forward Bench Mark

TP4 – Set forward of the bow on solid ground Positional

checks were made to:

Multi Beam Reference Point: X = 0.001 m , X = 0.009, and Z = 0.0 Starboard GPS: X

= 0.004 m, Y = 0.009 m, Z = 0.007 m
Port GPS: X = 0.005 m, Y = 0.010 m, Z = 0.010 m TP1: X = 0.002 m,
Y = 0.001 m, Z = 0.01 m

Setup 3:
Observing from TP4 and initializing on TP3 we collected checked points: Bow Bench Mark: X = 0.010 m, Y = 0.007 m, Z = 0.000 m
Starboard Forward Bench Mark: X = 0.010 m, Y = 0.007 m, Z = 0.000 m Port Forward Bench Mark: X = 0.009 m, Y = 0.014 m, Z = 0.000 m IMU: X = 0.004 m, Y = 0.000 m, Z = 0.018 m
IMU Offset: X = 0.007 m, Y = 0.002 m, Z = 0.009 m TP3: X = 0.002 m, Y = 0.001 m, Z = 0.002 m

## POST PROCESSING

Since the project was initialized using assumed positions and elevations, the collected points needed to be translated to a referenced coordinate system. Using ForeSight DXM, our observed IMU was translated N 0.000(m), E 0.000(m), and Elev 0.000(m).

## DISCUSSION

All sensor/benchmark coordinates are contained in spreadsheet "F 3002 2012.xls."

| NOAA BOAT R3002 | | | |
|---|---|---|---|
| | Reference Point IMU RM | | |
| NAME | X (Meters) | Y (Meters) | Z (Meters) |
| IMU OFFSET | 0.217 | 0.028 | 0.14 |
| IMU | 0.000 | 0.000 | 0.000 |
| SIDE SCAN TOW POINT | -4.509 | -0.004 | -2.352 |
| STARBOARD GPS (ARP) | -0.096 | 1.052 | -2.570 |
| PORT GPS (ARP) | -0.110 | -1.07 | -2.568 |
| DGPS | -0.104 | -0.008 | -2.492 |
| MULTIBEAM REFERENCE POINT | -0.923 | 1.768 | -1.336 |
| MULITBEAM POLE REFERENCE POINT TOP | -1.017 | 1.855 | -1.195 |
| MULTIBEAM POLE REFERENCE POINT BOTTOM | -1.042 | 1.830 | 0.887 |
| PORT AFT BENCH MARK | -2.407 | -1.487 | -1.029 |
| STARBOARD AFT BENCH MARK | -2.424 | 1.508 | -1.033 |
| BOW BENCH MARK | 5.530 | 0.008 | -1.087 |
| STARBOARD FORWARD BENCH MARK | 5.513 | 1.181 | -1.161 |
| PORT FORWARD BENCH MARK | 5.524 | -1.162 | -1.160 |