U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

# Data Acquisition & Processing Report

| | |
|---|---|
| Type of Survey: | Navigable Area |
| Project Number: | OPR-K371-TJ-18 |
| Time Frame: | May - August 2018 |

## LOCALITY

| | |
|---|---|
| State(s): | Texas |
| General Locality: | Offshore NE of Galveston Bay Entrance Channel |

## 2018

CHIEF OF PARTY
CDR Christiaan van Westendorp, NOAA

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Date:

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# Data Acquisition and Processing Report

**NOAA Ship *Thomas Jefferson***
Chief of Party: CDR Christiaan van Westendorp, NOAA
Year: 2018
Version: 1.0
Publish Date: 2018-07-17

# A System Equipment and Software

## A.1 Survey Vessels

### A.1.1 NOAA Ship THOMAS JEFFERSON (WTEA)

| | | |
|---|---|---|
| *Vessel Name* | NOAA Ship THOMAS JEFFERSON (WTEA) | |
| *Hull Number* | S222 | |
| *Description* | S222 is a steel hulled hydrographic survey ship built by Halter Marine, Inc., Moss Point, MS. | |
| *Dimensions* | *LOA* | 208 ft |
| | *Beam* | 45 ft |
| | *Max Draft* | 17 ft |
| *Most Recent Full Static Survey* | *Date* | 2016-09-01 |
| | *Performed By* | The IMTEC Group, Ltd. |

### A.1.2 Hydrographic Survey Launch 2903 (HSL 2903)

| | | |
|---|---|---|
| *Vessel Name* | Hydrographic Survey Launch 2903 (HSL 2903) | |
| *Hull Number* | 2903 | |
| *Description* | HSL 2903 is an aluminum hulled hydrographic survey launch built in 2017 by Willard Marine, Inc. HSL 2903 is designed and equipped to collect bathymetric data, side scan imagery, and water column profiles. | |
| *Dimensions* | *LOA* | 28 ft |
| | *Beam* | 10 ft |
| | *Max Draft* | 4 ft |

| | | |
|---|---|---|
| *Most Recent Full Static Survey* | *Date* | 2017-05-01 |
| | *Performed By* | National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch |
| *Most Recent Partial Offset Verification* | *Date* | 2018-05-04 |
| | *Method* | Physical confirmation of measurements. |

### A.1.3 Hydrographic Survey Launch 2904 (HSL 2904)

| | | |
|---|---|---|
| *Vessel Name* | Hydrographic Survey Launch 2904 (HSL 2904) | |
| *Hull Number* | 2904 | |
| *Description* | HSL 2904 is an aluminum hulled hydrographic survey launch built in 2017 by Willard Marine, Inc. HSL 2904 is designed and equipped to collect bathymetric data, side scan imagery, and water column profiles. | |
| *Dimensions* | *LOA* | 28 ft |
| | *Beam* | 10 ft |
| | *Max Draft* | 4 ft |
| *Most Recent Full Static Survey* | *Date* | 2017-05-01 |
| | *Performed By* | National Ocean Service - National Geodetic Survey (NGS) - Field Operations Branch |
| *Most Recent Partial Offset Verification* | *Date* | 2018-05-04 |
| | *Method* | Physical confirmation of measurements. |

## A.2 Echo Sounding Equipment

### A.2.1 Multibeam Echosounders

### A.2.1.1 Kongsberg Maritime AS EM2040

| | |
|---|---|
| *Manufacturer* | Kongsberg Maritime AS |
| *Model* | EM2040 |

<table>
<tr><td>Description</td><td>The Kongsberg EM2040 MBES is a high resolution shallow water MBES. The system is capable of operating at 200, 300, or 400 kHz frequencies, can provide across-track swath width up to 5.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 600 meters.<br><br>The standard practice aboard THOMAS JEFFERSON is to operate the EM2040 on S222 with a maximum swath width of 120 degrees and in Single Center Sector mode per HSTB recommendations.<br><br>The EM2040 is operated at the 300 kHz frequency for normal shallow water operations.<br><br>See the NOAA Ship THOMAS JEFFERSON EM710 and EM2040 Acceptance Testing Report included in the Appendices for a detailed discussion about the EM2040 system on S222.</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td>S222</td><td>
<table>
<tr><td>Component</td><td>Processor</td><td>Transceiver</td><td>Receiver</td><td>Projector</td></tr>
<tr><td>Model Number</td><td>EM2040</td><td>EM2040</td><td>EM2040</td><td>EM2040</td></tr>
<tr><td>Serial Number</td><td>CZC3410L1L</td><td>40072</td><td>334</td><td>236</td></tr>
<tr><td>Frequency</td><td>N/A</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td>Calibration</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td></tr>
<tr><td>Accuracy Check</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td></tr>
</table>
</td></tr>
<tr><td>2903</td><td>
<table>
<tr><td>Component</td><td>Processor</td><td>Transducer</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>EM2040</td><td>EM2040</td><td>EM2040</td></tr>
<tr><td>Serial Number</td><td>CZC746864F</td><td>281</td><td>392</td></tr>
<tr><td>Frequency</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td>Calibration</td><td>2018-05-17</td><td>2018-05-17</td><td>2018-05-17</td></tr>
<tr><td>Accuracy Check</td><td>2018-05-17</td><td>2018-05-17</td><td>2018-05-17</td></tr>
</table>
</td></tr>
<tr><td>2904</td><td>
<table>
<tr><td>Component</td><td>Processor</td><td>Transducer</td><td>Receiver</td></tr>
<tr><td>Model Number</td><td>EM2040</td><td>EM2040</td><td>EM2040</td></tr>
<tr><td>Serial Number</td><td>CZ7468666</td><td>282</td><td>393</td></tr>
<tr><td>Frequency</td><td>200-400 kHz</td><td>200-400 kHz</td><td>200-400 kHz</td></tr>
<tr><td>Calibration</td><td>2018-07-12</td><td>2018-07-12</td><td>2018-07-12</td></tr>
<tr><td>Accuracy Check</td><td>2018-07-12</td><td>2018-07-12</td><td>2018-07-12</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

### A.2.1.2 Kongsberg Maritime AS EM710

| | |
|---|---|
| *Manufacturer* | Kongsberg Maritime AS |
| *Model* | EM710 |

<table>
<tr><td>Description</td><td>The Kongsberg EM710-MK2 is a high resolution MBES system. The system is capable of operating at frequencies from 65 to 100 kHz for operations in shallow waters, can operate at frequencies down to 40 kHz for deep water operations, can provide across-track swath width up to 5.5 times water depth, provides single or multi-sector modes of operations, and can be used in depths up to 2800 meters.<br><br>The standard practice aboard THOMAS JEFFERSON is to operate the EM710 with a maximum swath width of 120 degrees per HSTB recommendations. The EM710 offers several modes of operations corresponding to survey depths; standard practice aboard the THOMAS JEFFERSON is to set the EM710 system to automatically operate in the mode of operation most appropriate for working depths.<br><br>See the NOAA Ship THOMAS JEFFERSON EM710 and EM2040 Acceptance Testing Report included in the Appendices for a detailed discussion about the EM2040 system on S222.</td></tr>
<tr><td>Inventory</td><td>
<table>
<tr><td>S222</td><td>
<table>
<tr><td>Component</td><td>Projector</td><td>Receiver</td><td>Processor</td></tr>
<tr><td>Model Number</td><td>EM 710</td><td>EM 710</td><td>EM 710</td></tr>
<tr><td>Serial Number</td><td>235</td><td>172</td><td>CZC3407HFV</td></tr>
<tr><td>Frequency</td><td>40-100 kHz</td><td>40-100 kHz</td><td>40-100 kHz</td></tr>
<tr><td>Calibration</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td></tr>
<tr><td>Accuracy Check</td><td>2018-05-04</td><td>2018-05-04</td><td>2018-05-04</td></tr>
</table>
</td></tr>
</table>
</td></tr>
</table>

### A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

### A.2.3 Side Scan Sonars

#### A.2.3.1 Klein Marine Systems, Inc. 5000 v2

| | |
|---|---|
| *Manufacturer* | Klein Marine Systems, Inc. |
| *Model* | 5000 v2 |

<table>
<tr><td>Description</td><td>The Klein 5000 v2 Side Scan Sonar (SSS) system is a beam-forming acoustic imagery device. The integrated system includes a Klein 5000 towfish, a Transceiver/Processing Unit (TPU), and a computer for user interface. Stern-towed units also include a tow cable telemetry assembly. The towfish operates at a frequency of 455kHz and a vertical beam angle of 40°, and can resolve up to 5 discrete received beams per transducer stave. The system is capable of ranges of up to 250 meters. The Klein 5000 v2 model can also be used to collect bathymetric data using acoustic phase differencing technology. The Klein 5000 v2 systems are only used to collect SSS imagery on THOMAS JEFFERSON.<br><br>The Klein 5000 v2 is deployed in a stern-towed configuration on S222.<br><br>All Klein systems were upgraded with new TPUs in 2017.</td></tr>
<tr><td>Inventory</td><td><table><tr><td>S222</td><td><table>
<tr><td>Component</td><td>TPU</td><td>Towfish</td></tr>
<tr><td>Model Number</td><td>5000 v2</td><td>5000 v2</td></tr>
<tr><td>Serial Number</td><td>778</td><td>385</td></tr>
<tr><td>Frequency</td><td>455 kHz</td><td>455 kHz</td></tr>
<tr><td>Calibration</td><td>2018-05-04</td><td>2018-05-04</td></tr>
<tr><td>Accuracy Check</td><td>2018-05-04</td><td>2018-05-04</td></tr>
</table></td></tr></table></td></tr>
</table>

### A.2.3.2 Klein Marine Systems, Inc. 5000

<table>
<tr><td>Manufacturer</td><td>Klein Marine Systems, Inc.</td></tr>
<tr><td>Model</td><td>5000</td></tr>
<tr><td>Description</td><td>The Klein 5000 system used on S222 is an older version of the 5000 v2 system. The specifications of the 5000 system are identical to the 5000 v2 system in all substantial aspects relating to system performance. The towfish units on 5000 systems are smaller than the towfish units for the 5000 v2 system and are deployed on the HSLs in a hull-mounted configuration.<br><br>All Klein systems were upgraded with new TPUs in 2017.</td></tr>
<tr><td>Inventory</td><td><table><tr><td>2903</td><td><table>
<tr><td>Component</td><td>TPU</td><td>Towfish</td></tr>
<tr><td>Model Number</td><td>5000</td><td>5000</td></tr>
<tr><td>Serial Number</td><td>009</td><td>319</td></tr>
<tr><td>Frequency</td><td>455 kHz</td><td>455 kHz</td></tr>
<tr><td>Calibration</td><td>2018-05-04</td><td>2018-05-04</td></tr>
<tr><td>Accuracy Check</td><td>2018-05-04</td><td>2018-05-04</td></tr>
</table></td></tr></table></td></tr>
</table>

## A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

### A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

## A.3 Manual Sounding Equipment

### A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

### A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

### A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

### A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

## A.4 Horizontal and Vertical Control Equipment

### A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

### A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

### A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

### A.4.4 Levels

No levels were utilized for data acquisition.

## A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment were utilized for data acquisition.

## A.5 Positioning and Attitude Equipment

### A.5.1 Positioning and Attitude Systems

#### A.5.1.1 Applanix Corporation POS MV 320 Version 5

| | |
|---|---|
| *Manufacturer* | Applanix Corporation |
| *Model* | POS MV 320 Version 5 |

| | |
|---|---|
| *Description* | The Applanix POS MV 320 Version 5 (Position and Orientation System for Marine Vessels, hereafter 'POS MV v5') is a GNSS Inertial Navigation System that provides high frequency and highly accurate vessel trajectory (both navigation/position and attitude/orientation) data. The system incorporates data from an Inertial Motion Unit (IMU) and dual multi-constellation Global Navigation Satellite System (GNSS) receivers. Advanced proprietary Kalman Filtering techniques are used to provide a blended navigation and trajectory solution in real-time that is both highly accurate and reliable. The POS MV v5 also computes vessel heave (both instantaneous and delayed heave values). The POS MV v5 system is integrated with all acquisition systems on all platforms. Data from the POS MV v5 is applied to echosounder data in real-time and logged for post-processing and/or archiving.<br><br>The POS MV v5 produces attitude data in three axes (roll, pitch, and heading) to an accuracy of 0.02° or better. Real-time heave measurements supplied by the POS/MV maintain an accuracy of 5% of the measured vertical displacement or 5 cm (whichever is greater) for vertical motions less than 20 seconds in period. The standard practice on THOMAS JEFFERSON is to configure the Heave Bandwidth filter with a damping coefficient of 0.707 and to apply a high pass filter that is determined by the longest swell period encountered on the survey grounds. The POS MV v5 also calculates a 'delayed heave' value (Applanix calls this 'TrueHeave'). The Applanix delayed heave algorithm uses a delayed filtering technique to eliminate many of the artifacts present in real time heave data. Applanix delayed heave measurements maintain an accuracy of 2% of the measured vertical displacement or 2 cm (whichever is greater) for vertical motions less than 20 seconds in period. Delayed heave measurements are logged and applied to MBES data in post processing.<br><br>A graphical user interface provides visual representations and summary statistics of data quality in real-time. Performance parameters are monitored by acquisition hydrographers in real-time and checked against HSSD requirements.<br><br>Position and trajectory data from the POS MV v5 system is applied in both real-time and post-processed applications. Navigation and attitude data is applied to all echosounder data in real-time. Raw data from the POS MV v5 can also be post-processed after acquisition to achieve trajectory solutions that are more accurate than those achieved in real-time by using forward/backward processing methods. Post-processing is conducted using the Applanix POSPac Mobile Mapping Suite (MMS) software suite. Post-processing methodology is described elsewhere in this document. |

| | | | | |
|---|---|---|---|---|
| *Inventory* | *S222* | *Component* | IMU | PCS |
| | | *Model Number* | LN200 (v4) | POS MV 320 v5 |
| | | *Serial Number* | 1047 | 6497 |
| | | *Calibration* | 2018-05-04 | 2018-05-04 |
| | *2903* | *Component* | IMU | PCS |
| | | *Model Number* | LN200 (v3) | POS MV 320 v5 |
| | | *Serial Number* | 131 | 8927 |
| | | *Calibration* | 2018-05-04 | 2018-05-04 |
| | *2904* | *Component* | IMU | PCS |
| | | *Model Number* | LN200 (v4) | POS MV 320 v5 |
| | | *Serial Number* | 356 | 8958 |
| | | *Calibration* | 2018-05-04 | 2018-05-04 |

### A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

### A.5.3 GPS

GPS equipment was not utilized for data acquisition.

### A.5.4 Laser Rangefinders

Laser rangefinders were not utilized for data acquisition.

## A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

# A.6 Sound Speed Equipment

## A.6.1 Moving Vessel Profilers

### A.6.1.1 Rolls-Royce Group ODIM Brooke Ocean MVP100 Moving Vessel Profiler (MVP)

<table>
<tr><td>Manufacturer</td><td colspan="3">Rolls-Royce Group ODIM Brooke Ocean</td></tr>
<tr><td>Model</td><td colspan="3">MVP100 Moving Vessel Profiler (MVP)</td></tr>
<tr><td>Description</td><td colspan="3">S222 is equipped with a Rolls-Royce Group Brooke Ocean MVP100 Moving Vessel Profiler (MVP). The MVP system consists of a sensor towfish, a conductor/tow cable, a computer controlled high speed hydraulic winch, and a cable metering system. A Conductivity-Temperature-Depth (CTD) or direct-read sound speed sensor is housed in the sensor towfish and interfaced with the ship acquisition system via the conductor/tow cable. The MVP system provides a means of collecting full water-column data while S222 remains underway.<br><br>The MVP system on S222 has 320 m of cable and can be used to take water-column profiles of approximately 150 m in depth at speeds of approximately 10 kts.<br><br>The MVP product line is now owned by AML Oceanographic.</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">S222</td><td>Component</td><td>MVP System</td></tr>
<tr><td>Model Number</td><td>MVP 100</td></tr>
<tr><td>Serial Number</td><td>N/A</td></tr>
<tr><td>Calibration</td><td>2018-05-04</td></tr>
</table>

## A.6.2 CTD Profilers

### A.6.2.1 Sea-bird Electronics SBE 19plus

| | |
|---|---|
| *Manufacturer* | Sea-bird Electronics |
| *Model* | SBE 19plus |

| | |
|---|---|
| *Description* | The Sea-Bird Electronics SBE 19plus SeaCAT profiler measures conductivity, temperature, and depth (CTD) in marine and/or freshwater environments. The SBE 19plus is rated for use at depths of up to 600 meters and is capable of sampling at a rate of 4 measurements per second. CTD values are used to calculate the speed of sound through the water column.<br><br>SBE 19plus profilers are the primary means of obtaining water column data on HSL 2903 and HSL 2904.<br><br>SBE 19plus profilers are used primarily as a backup means of obtaining water column data and/or deep-water water column data on S222. |
| *Inventory* | *Component*: CTD<br>*Model Number*: SBE 19plus<br>*Serial Number*: 4487<br>*Calibration*: 2018-05-04<br>*Component*: CTD<br>*Model Number*: SBE 19plus<br>*Serial Number*: 4343<br>*Calibration*: 2018-05-27<br>*Component*: CTD<br>*Model Number*: SBE 19plus<br>*Serial Number*: 6667<br>*Calibration*: 2018-05-27 |

### A.6.2.2 AML Oceanographic AML Micro CTD

| | |
|---|---|
| *Manufacturer* | AML Oceanographic |
| *Model* | AML Micro CTD |
| *Description* | The Micro CTD is a sensor used to measure conductivity, temperature and depth of water. The Micro CTD provides conductivity measurements at a resolution of 0.0015 mS/cm with an accuracy of 0.01 mS/cm, temperature measurements at a resolution of 0.001 degree C with an accuracy of plus/minus 0.005 degree C, and pressure at a resolution of 0.1 dBar with an accuracy of plus/minus 0.05 % of measurement.<br><br>The AML Micro CTD is attached to the MVP100 towfish on S222 to provide water column data to the ship data acquisition system. |

| | | |
|---|---|---|
| *Inventory* | *Component* | Probe |
| | *Model Number* | AML Micro CTD |
| | *Serial Number* | 8613 |
| | *Calibration* | 2018-05-04 |

### A.6.2.3 AML Oceanographic AML MVP-X

| | |
|---|---|
| *Manufacturer* | AML Oceanographic |
| *Model* | AML MVP-X |
| *Description* | The AML MVP-X is a multi-parameter sensor designed specifically for use with the AML Moving Vessel Profiler (MVP) models. The MVP-X is highly configurable and is compatible with all AML Xchange (tm) oceanographic sensors. The MVP-X configuration used on S222 includes conductivity, temperature and pressure sensors: the conductivity sensors provide a sensor range of 0-90 mS/cm, a resolution of 0.001 mS/cm, with an accuracy of plus/minus 0.01 mS/cm; the temperature sensors provide a sensor range of -5 to +45 Deg C, a resolution of 0.001 Deg C, with an accuracy of plus/minus 0.005 Deg C; the pressure sensors provide a sensor range of 0 to 1000 dBar, a resolution of 0.02% of measurement, with an accuracy of 0.05% of measurement. The main instrument housings on the MVP-X units are rated for operation at pressures up to 6000 dBar.<br><br>The AML MVP-X units are not normally deployed and are used as backup sensors to the MicroCTD used in the MVP100 sensor towfish. |

| | | | |
|---|---|---|---|
| *Inventory* | *Component* | Probe | Probe |
| | *Model Number* | AML MVP-X | AML MVP-X |
| | *Serial Number* | 9001 | 9006 |
| | *Calibration* | 2018-05-04 | 2018-05-04 |

## A.6.3 Sound Speed Sensors

### A.6.3.1 Teledyne Reson (formally RESON A/S) Reson SVP-70 and SVP-71 Sound Speed Sensors

| | |
|---|---|
| *Manufacturer* | Teledyne Reson (formally RESON A/S) |
| *Model* | Reson SVP-70 and SVP-71 Sound Speed Sensors |

| | | | |
|---|---|---|---|
| *Description* | The Reson SVP-70 and SVP-71 are direct-read sound velocity measurement devices. The SVP devices obtain sound speed measurements by directly measuring the travel time of sound pulses along a set 125 mm transmission path. The SVP systems are capable of reading sound speeds from 1350 to 1800 m/s with a resolution of 0.01 m/s (±0.15m/s) at a sampling rate of 20 Hz.<br><br>The SVP-70 and SVP-71 provide identical sound speed measurement capabilities and differ only in housing construction and operational depth ratings; the housing of the SVP-70 is made entirely of titanium while the SVP-71 housing is made of hard anodized sea-water resistant aluminum.<br><br>The Reson SVPs provide real-time surface sound speed data to the Kongsberg MBES systems on HSL 2903 and HSL 2904. An SVP is mounted close to the EM2040 transducers on each launch. | | |
| *Inventory* | *2903* | *Component* | Probe |
| | | *Model Number* | SVP-71 |
| | | *Serial Number* | 4211067 |
| | | *Calibration* | 2018-05-04 |
| | *2904* | *Component* | Probe |
| | | *Model Number* | SVP-70 |
| | | *Serial Number* | 1013077 |
| | | *Calibration* | 2018-05-04 |

### A.6.3.2 Valeport Limited Modus SVS

| | |
|---|---|
| *Manufacturer* | Valeport Limited |
| *Model* | Modus SVS |
| *Description* | The Modus SVS is a thru-hull sound velocity sensor.<br><br>The sound speed sensor used in the system is a direct-read 'time of flight' sound speed sensor. The Modus models used aboard S222 use a 100mm measurement path and include temperature sensors. The sound speed sensor can measure sound in fresh water or marine environments with a measurement range of 1400-1600 m/s, at a resolution of 0.001 m/s, with an accuracy of ± 0.03 m/s. The thru-hull port where the sound speed sensor is deployed is located adjacent and aft of the transducer fairing.<br><br>Note on calibration date for Modus SVS 33711: The unit was calibrated on 12/14/2016 but was stowed in a temperature controlled space and not used until installed for ship use in Janurary 2018. |

| | | | | |
|---|---|---|---|---|
| *Inventory* | *S222* | *Component* | Probe | Probe |
| | | *Model Number* | Modus SVS | Modus SVS |
| | | *Serial Number* | 33711 | 33747 |
| | | *Calibration* | 2018-05-04 | 2018-05-04 |

### A.6.4 TSG Sensors

No surface sound speed sensors were utilized for data acquisition.

### A.6.5 Other Sound Speed Equipment

No surface sound speed sensors were utilized for data acquisition.

## A.7 Computer Software

### A.7.1 Caris HIPS

| | |
|---|---|
| *Manufacturer* | Caris |
| *Software Name* | HIPS |
| *Version* | 10.4 |
| *Installation Date* | 2018-05-04 |
| *Use* | Processing |

### A.7.2 Caris BASE Editor

| | |
|---|---|
| *Manufacturer* | Caris |
| *Software Name* | BASE Editor |
| *Version* | 4.4 |
| *Installation Date* | 2018-05-04 |
| *Use* | Processing |

### A.7.3 NOAA Pydro

| | |
|---|---|
| *Manufacturer* | NOAA |
| *Software Name* | Pydro |

| | |
|---|---|
| *Version* | 18 |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition and Processing |

#### A.7.4 HYPACK - A Xylem Brand HYPACK

| | |
|---|---|
| *Manufacturer* | HYPACK - A Xylem Brand |
| *Software Name* | HYPACK |
| *Version* | 2018 |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition |

#### A.7.5 Applanix Corporation POSPac MMS

| | |
|---|---|
| *Manufacturer* | Applanix Corporation |
| *Software Name* | POSPac MMS |
| *Version* | 8.2.1 |
| *Installation Date* | 2018-05-04 |
| *Use* | Processing |

#### A.7.6 Applanix Corporation POSView

| | |
|---|---|
| *Manufacturer* | Applanix Corporation |
| *Software Name* | POSView |
| *Version* | 8.32 |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition |

#### A.7.7 QPS, Inc Fledermaus

| | |
|---|---|
| *Manufacturer* | QPS, Inc |
| *Software Name* | Fledermaus |
| *Version* | 7.4.0d |
| *Installation Date* | 2018-05-04 |
| *Use* | Processing |

#### A.7.8 ESRI, Inc. ArcGIS

| | |
|---|---|
| *Manufacturer* | ESRI, Inc. |
| *Software Name* | ArcGIS |
| *Version* | 10.3 |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition and Processing |

#### A.7.9 Kongsberg Maritime AS Seafloor Information System (SIS)

| | |
|---|---|
| *Manufacturer* | Kongsberg Maritime AS |
| *Software Name* | Seafloor Information System (SIS) |
| *Version* | 4.3.0 (EM710) and 4.3.2 (EM2040) |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition |

#### A.7.10 Klein Marine Systems, Inc SonarPro

| | |
|---|---|
| *Manufacturer* | Klein Marine Systems, Inc |
| *Software Name* | SonarPro |
| *Version* | 14.1 |
| *Installation Date* | 2018-05-04 |
| *Use* | Acquisition |

## A.8 Bottom Sampling Equipment

### A.8.1 Bottom Samplers

#### A.8.1.1 Kahlisco Mud Snapper 214WA100 (AKA 'The Nibbler')

| | |
|---|---|
| *Manufacturer* | Kahlisco |
| *Model* | Mud Snapper 214WA100 (AKA 'The Nibbler') |
| *Description* | The Kahlisco Mud Snapper is a hand held bottom sampler used to take bottom samples from HSLs 2903 and 2904. The Mud Snapper is a foot-trip model clam shell style bottom sampler. This sampler is designed to collect unconsolidated |

| | |
|---|---|
| | sediments up to the size of small pebbles. The sampler is fabricated from sturdy bronze and stainless steel materials for trouble-free service in a marine environment.<br><br>The unit consists of a long threaded post surrounded by a strong compression spring that presses against the jaws at one end and an adjustable screw cap at the upper end. By turning this threaded cap the spring-compression is adjusted, changing the strength at which the jaws close. A shackle is attached through a hole on the top of the post and a line attached. Due to the small of this sampler, it may be deployed either by using a heavy duty fishing pole or by using a handline. |

#### A.8.1.2 Ponar Wildco Model #1728

| | |
|---|---|
| *Manufacturer* | Ponar Wildco |
| *Model* | Model #1728 |
| *Description* | The Ponar Wildco is a winch-deployed bottom sampler used aboard S222. The sampler is a Ponar type grab sampler of a design commonly used to sample a wide variety of sediment types. The sampler design uses self-tripping center hinged jaws and a spring loaded trigger pin that releases when the sampler makes impact with the bottom. The sampler’s jaws are closed by the scissor action of the lever arms when the sampler is retrieved. The sampling area is 6" x 6". |

#### A.8.1.3 NOAA-UNH NOAA-UNH Image Grab Sampler (IGS) v1.0

| | |
|---|---|
| *Manufacturer* | NOAA-UNH |
| *Model* | NOAA-UNH Image Grab Sampler (IGS) v1.0 |
| *Description* | The IGS is used to collect imagery of the seabed at a bottom sample location. The system utilizes a GoPro (tm) camera and several dive-rated flashlights positioned on a shaft with a stabilizing float. The frame set up connects between the deployment line and bottom sampler or optional sample frame. The Ponar Wildco grab sampler is used to obtain the physical samples. Sample imagery is downloaded from the GoPro camera following each deployment. |

# B System Alignment and Accuracy

## B.1 Vessel Offsets and Layback

### B.1.1 Vessel Offsets

All offsets for S222 are derived from full surveys performed by Kongsberg USA-contracted personnel and have been verified by Hydrographic Systems and Technology Branch (HSTB) personnel. All offsets are tracked and updated as needed. Offsets values are known in the vessel reference frame, the IMU reference frame, and Kongsberg EM710 reference frame. Offset values for the Kongsberg MBES systems are entered into SIS and the ship's Caris HIPS Hydrographic Vessel File (HVF), with the exception of the orthogonal offsets between the primary Applanix GNSS sensor antenna and the Applanix IMU. The offset between the primary GNSS antenna and the IMU is applied to the POS MV. The POS MV provides navigation and attitude data in the IMU reference frame at the IMU reference point. All other offsets are applied to data during the SVP or Merge processing steps in CARIS HIPS.

Offsets are applied to side scan sonar data in Caris HIPS during the Compute Towfish Navigation step.

All offsets for HSL 2903 and HSL 2904 are derived from full vessel surveys performed by NGS personnel. The reference point for the launches is the IMU.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the Appendices to this report. HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere and include all of the requested values for the DAPR necessary to reproduce an HVF.

#### B.1.1.1 Vessel Offset Correctors

See included HVFs for information on applied correctors.

#### B.1.2 Layback

Towfish positioning is provided to Caris HIPS using cable-out values registered by the Totco cable counter and recorded in the SonarPro SDF files. SonarPro uses Payout and Towfish Depth to compute towfish positions. The towfish position is calculated from the position of the tow point using the cable-out value received by SonarPro from the cable payout meter, the towfish pressure depth (sent via a serial interface from the Klein 5000 TPU to the SonarPro software), and the Course Made Good (CMG) of the vessel. This method assumes that the cable is in a straight line. Therefore, no catenary algorithm is applied at the time of acquisition, but in processing, Caris SIPS applies a 0.9 coefficient to account for the catenary.

Layback error is calculated by running a side scan certification test. This test consists of running parallel to a known feature at varying ranges from nadir to ensonify the target in the near-field (approximately 15% of range scale in use), mid-field (approximately 50 % of range scale in use), and far-field (approximately 85% of the range scale in use). The test requires that each side of the sonar ensonify the feature at each of these areas in the swath. Then the test is repeated in a direction that is orthogonal to the original set of lines such that the feature is ensonified a total of 12 times. A successful test will detect the feature in at least 10 of the 12 passes. For hull-mounted systems, the selected contact positions must be within 5m; for towed systems, the contact positions must be within 10m. Layback error is the amount of correction that must be applied to minimize the distance between contact positions.

### B.2 Static and Dynamic Draft

#### B.2.1 Static Draft

Static draft is measured on the S222 using a Sutron Bubbler system. The waterline for the ship when fully loaded with fuel and ballasted normally is approximately 35cm below the reference point of the ship; the waterline may change by as much as +/- 30cm over the course of a field season.

The waterline for S222 is measured as needed. Waterline measurements are always taken at the beginning and end of 2-3 week survey legs. When feasible, waterline measurements are taken at weekly intervals and when the ship is fueled or ballasted. The values are kept in a static draft log and periodically updated in the HVF. Once applied in the HVF, all affected lines have SVP re-applied and are then merged so that the updated waterline measurements will be applied.

The waterline for HSL platforms is measured using physical measurements from the waterline of the vessel to physical known benchmarks.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

#### B.2.1.1 Static Draft Correctors

### B.2.2 Dynamic Draft

Dynamic draft for all platforms was measured using the Post Processed Kinematic GPS method outlined in section 1.4.2.1.2.1 of NOAA's FPM. To reduce the effect of any potential current, reciprocal lines were run at each RPM step in order to get an average speed over ground for each RPM. This average speed was used to estimate the vessel's speed through the water. Dynamic draft and vessel offsets corrector values are stored in the HIPS Vessel Files (HVF).

An average of dynamic draft values from years prior to 2018 is used for S222 for the 2018 field season. Dynamic draft values for HSL 2903 and 2904 were determined using the ERDDM method during HSRR activities in 2018.

In ERS surveys (those that use recorded GPS heights corrected via a VDatum SEP model to achieve tidal datum) the dynamic draft correction is not applied to the soundings.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

#### B.2.2.1 Dynamic Draft Correctors

See included HVFs for information on applied correctors.

## B.3 System Alignment

### B.3.1 System Alignment Methods and Procedures

THOMAS JEFFERSON conducts MBES calibration tests during annual HSRR activities for each individual multibeam system on the ship and her launches.

The procedure used to calibrate launch MBES systems is derived from the procedure outlined in section 1.5.5.1 of the Field Procedures Manual dated April 2014.

Offset values for all platforms were determined using the Caris HIPS MBES calibration tool.

All calibration reports can be found in the Appendix Folder.

#### B.3.1.1 System Alignment Correctors

See included HVFs and calibration reports for information on applied correctors.

# C Data Acquisition and Processing

## C.1 Bathymetry

### C.1.1 Multibeam Echosounder

#### Data Acquisition Methods and Procedures

All multibeam data on THOMAS JEFFERSON platforms is logged using Kongsberg Seafloor Information System (SIS) in the Kongsberg ALL (.all) file format.

During acquisition aboard THOMAS JEFFERSON, the hydrographer:

- Monitors the SIS interface for errors and data quality

- Monitors the SIS interface for indication of sound speed changes requiring a cast, and conducts casts as necessary

- Monitors the Hysweep interface in HYPACK

- Monitors the vessel speed and requests the bridge to adjust as necessary to ensure density and coverage specifications are met

**Data Processing Methods and Procedures**

MBES is processed using Caris HIPS and the Pydro Charlene.

S222 Workflow:

Caris HIPS is used to conduct the following basic processing steps  for S222:

1. Conversion: Kongsberg ALL (.all) MBES data is converted into the Caris project structure.

2. Load Delayed Heave: TrueHeave data from Applanix POS MV raw logged data is applied to all MBES sounding.

3. Sound Velocity Correct: MBES data is sound velocity corrected using the the Caris method.

4. Compute GPS Tide: GPS tides are computed using real-time ellipsoid height logged in the Kongsberg ALL files and a VDatum separation model.

5. Merge: MBES data is merged to apply appropriate correctors.

6. Compute Total Propagated Uncertainty (TPU): Uncertainty is computed based on parameters discussed elsewhere in this report.

7. Create Surface: Combined Uncertainty and Bathymetric Estimator (CUBE) bathymetric surfaces are created in accordance with relevant project and OCS survey specifications.

S222 workflow notes:

The procedure outlined above reflects the general workflow use on the ship to process MBES data. An additional step may be added to the workflow for the application of Smooth Best Estimate Trajectory (SBET) files. SBETs are loaded as Auxiliary data in cases where SBET files are used to provide improved ellipsoid height positioning; this processing step occurs after loading Delayed Heave and before Sound Velocity Correcting the data.

The unique integration setup for S222 requires that the Load Delayed Heave and Sound Velocity Correction steps be executed in HIPS in order to accurately Compute GPS Tides. This counter-intuitive requirement is the result of the equipment settings used on S222 to integrate multiple MBES systems (EM2040 and EM710) with one Attitude and Navigation sensor (POS MV v5). See the TJ EM710 and EM2040 Acceptance Report included in the Appendices to this report for further information about this requirement.

HSL workflow:

Caris HIPS is used to conduct the following basic processing steps for HSL 2903 and HSL 2904:

1. Conversion: Kongsberg ALL (.all) MBES data is converted into the Caris project structure.

2. Compute GPS Tide: GPS tides are computed using real-time ellipsoid height logged in the Kongsberg ALL files and a VDatum separation model.

3. Merge: MBES data is merged to apply appropriate correctors.

4. Compute Total Propagated Uncertainty (TPU): Uncertainty is computed based on parameters discussed elsewhere in this report.

5. Create Surface: CUBE bathymetric surfaces are created in accordance with relevant project and OCS survey specifications.

HSL workflow notes:

The Load Delayed Heave and Sound Velocity Correction processing steps are not required for HSL processing workflows. SBETs are loaded as Auxiliary data in cases where SBET files are used to provide improved ellipsoid height positioning; this processing step occurs after initial data Conversion and before the Compute GPS Tides step.

Charlene:

Charlene is a Pydro utility that automates the processing workflows described above. The utility is essentially a ‘software wrapper’ that provides a single user interface that can be used to initiate standardized processing workflows. Charlene utilizes Caris and Applanix software Application Programing Interface utilities to initiate a given processing workflow.

Charlene is used for all standard processing workflows aboard THOMAS JEFFERSON.

Other notes:

Workflows utilizing traditional tides are no longer used aboard THOMAS JEFFERSON.

### C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

#### C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

#### C.1.4 Gridding and Surface Generation

#### C.1.4.1 Surface Generation Overview

CUBE gridded surfaces are generated in Caris HIPS following initial bathymetric data processing.

Single resolution CUBE surfaces are used for daily quality control and directed editing purposes.

Gridded bathymetric surfaces which comply with Project Instruction and HSSD requirements are generated following the completion of on-site acquisition operations and are used for post-acquisition survey processing.

#### C.1.4.2 Depth Derivation

CUBE and Variable Resolution (VR) parameter files provided by HSD Operations are used to ensure that gridding parameters and surface computation algorithms comply with the HSSD requirements.

Filters are used on a case-by-case basis as determined by the hydrographer. Refer to the Descriptive Report for more information.

#### C.1.4.3 Surface Computation Algorithm

MBES data is gridded using Single Resolution or Variable Resolution CUBE algorithms; these algorithms are implemented in the Caris HIPS surface creation tools used to create gridded bathymetric surfaces.

Resolution is dictated by the Project Instructions and section 5.2.2 of the HSSD.

HSD gridding parameter files are used to ensure that gridding parameters and surface computation algorithms comply with the HSSD requirements.

THOMAS JEFFERSON submits Single Resolution surfaces in lieu of Variable Resolution surfaces when HSSD requirements allow.

## C.2 Imagery

#### C.2.1 Multibeam Backscatter Data

**Data Acquisition Methods and Procedures**

Backscatter data on THOMAS JEFFERSON are logged in the Kongsberg ALL (.all) file format using Kongsberg SIS software.

**Data Processing Methods and Procedures**

Backscatter data are processed using the FMGT module of the QPS Fledermaus software package in accordance with OCS standard data processing methods.

### C.2.2 Side Scan Sonar

**Data Acquisition Methods and Procedures**

Side scan sonar data are logged in the SDF (.sdf) file format using SonarPro.

During acquisition the hydrographer:

- Monitors range, towfish height, heading, pitch, roll, latitude, longitude, speed, pressure, and temperature;

- Adjusts towfish height (for operations aboard THOMAS JEFFERSON)

**Data Processing Methods and Procedures**

Side scan sonar data are manually processed as follows:

1. Raw SDF data are converted into the Caris processed data format using the Caris HIPS data conversion utility.

2. The processor scans all navigation and attitude data; erroneous data are either flagged for further inspection or rejected with interpolation.

3. Towfish navigation and contact positions are recomputed using the ‘Re-compute Towfish’ process in Caris HIPS.

4. Each SSS line is visually scanned and significant contacts are marked by at least two independent processors.

5. Mosaic surfaces are created using the Caris HIPS ‘Create Mosaic’ process

Side scan data are automatically processed using Charlene in substantially the same way as described above for manual processing. The only exception is that towfish navigation is often re-computed twice: in this case, the ‘Re-compute Towfish’ towfish step is run once during the initial Charlene batch process and again after towfish attitude and/or navigation data have been edited by a processor.

### C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

## C.3 Horizontal and Vertical Control C.3.1

### Horizontal Control

### C.3.1.1 GNSS Base Station Data

GNSS base station data were not acquired.

### C.3.1.2 DGPS Data

Differential GPS (DGPS) data were not acquired.

### C.3.2 Vertical Control

### C.3.2.1 Water Level Data

**Data Acquisition Methods and Procedures**

THOMAS JEFFERSON uses the Fugro Marinestar satellite based corrector service to provide realtime correction to the horizontal position and ellipsoid height for all data acquisition and initial processing. The corrector signal is received on the L1 channel of the POS MV primary GPS antenna and logged directly into the POS MV.

In the event of issues with the real-time solution, the raw POS files produced during acquisition can be post-processed using POSPac MMS software to produce a trajectory solution in the WGS84 reference frame and an associated uncertainty file containing the realtime uncertainty estimates of the position and attitude data.

THOMAS JEFFERSON does not normally install GNSS reference stations or temporary tide stations for operations on the East Coast. Data from permanently installed GNSS reference stations and/or tide stations (typically maintained by NGS and CO-OPS, respectively) may be used in certain workflows (described below).

**Data Processing Methods and Procedures**

THOMAS JEFFERSON reduces all data to chart datum via Ellipsoidally Referenced Survey (ERS) workflows for all surveys.

GPS Tides:

The ‘Compute GPS Tides’ process in Caris HIPS is the primary means by which bathymetric data is reduced to chart datum. The Compute GPS Tides step references all MBES data to an ellipsoid and then applies a separation model to the ellipsoidally referenced data to achieve reduction to chart datum. The separation model is an XYZ surface that represents the difference between the ellipsoid and chart datum for the a given geographic area. The XYZ separation model used for typical NOAA workflows is delivered as a Caris CSAR file and represents the difference between the WGS84 ellipsoid and MLLW at a given location.

All separation models for waters in which THOMAS JEFFERSON operates are derived from the NGS Vertical Datum (VDatum) program. Separation models are usually generated, approved and disseminated by HSD Ops.

GNSS positioning methods employed to meet ERS specifications include the methods described below:

Vertical control requirements are satisfied through the use of one or more of the following methods.

Real-time Precise Point Positioning (RTPPP):

THOMAS JEFFERSON uses the Fugro Marinestar satellite based corrector service to provide real-time correction to the horizontal position and ellipsoid height for all data acquisition and initial processing. The corrector signal is received on the L1 channel of the POS MV primary GPS antenna. Marinestar correctors are used in the real-time POS MV trajectory solution and are logged in POS MV raw data files.

Ellipsoid height values derived from the Marinestar corrected POS MV real-time trajectory solution are logged in all Kongsberg MBES data. The ellipsoid height data present in the Kongsberg MBES files are normally used for all ‘GPS Tides’ computations in Caris HIPS.

In the event of issues with the real-time solution, the POS files produced during acquisition can be processed through the POSPac MMS software to produce an SBET in the WGS84 reference frame and an RMS file containing the realtime uncertainty estimates of the position and attitude data.

Real-time corrected ellipsoid height is recorded directly in Kongsberg MBES data logged through the Kongsberg SIS program on THOMAS JEFFERSON and is used when processing ship MBES data in CARIS HIPS.

Post-processed Precise Point Positioning (5P):

Raw GNSS-INS observables and Marinestar corrector data logged through POSView can be post-processed in POSPac MMS to provide a trajectory solution that can be applied to MBES data in CARIS HIPS. The post-processed PPP processing workflow is normally only used for crosslines and when problems arise in the real-time solution data.

Inertially Aided Post-Processed Kinematic (IAPPK):

Inertially Aided Post-Processed Kinematic (IAPPK) may be used in some situations. An IAPPK solution is created by combining GPS/GNSS satellite ephemeris and clock data with position information downloaded from a network of Continually Operating Reference Stations (CORS). The resulting position data are corrected for the effects of atmospheric interference on the GPS signal. The corrected GPS position is then combined with the vessel's inertial data using the POSPac MMS program to create an SBET. The resulting position can be used to apply higher quality navigation information to the processed data.

RTX:

Trimble RTX is a Precise Point Positioning technology similar to the G2 Fugro Marinestar service. The positioning algorithms used by Trimble RTX result in positioning solutions that generally achieve vertical positioning accuracies better than 6 cm (95% real-time and post-processed accuracy). RTX solutions are only available through post-processing in POSPac MMS software as utilized by NOAA and for marine applications. THOMAS JEFFERSON does not currently have regular access to an RTX subscription. The information presented above is noted for reference purposes only.

Non-ERS vertical control approaches:

Two ‘legacy’ workflows could potentially be used to reduce data to chart datums in the event that ERS specifications cannot be achieved. The following workflows are briefly described for reference purposes only.

Discrete Zoned Tides:

This method utilizes one or more National Water Level Observation Network (NWLON) water level gauges and a discrete zoned tidal modal to determine vertical control correctors to be applied to soundings at a given location and time. Co-range and co-phase measurements from the NWLON stations are used to break the project area into zones, each of which has a distinct time-of-tide and range-of-tide corrector. CO-OPS provides the field unit with a Caris compatible file which takes observed water levels from surrounding gauges, computes the time and range correctors for each zone, and uses the zoned data to reduce bathymetric soundings to MLLW. THOMAS JEFFERSON does not install tertiary gauges in support of tidal modeling. After completion of a survey area, CO-OPS verifies all zoning and water level data.

TCARI Tides:

Tidal Constituent and Residual Interpretor (TCARI) is an alternative to discrete zoning. A TCARI grid is a triangulated network that uses two or more water level gauges to create a weighted network across the survey area. Each point on the grid has a discrete tidal interpolation that is based on the horizontal nearness of a water level gauge, the harmonic constants of the area, and the residual water levels. Bathymetric data are then reduced to MLLW using the TCARI tool in Pydro. Like zoned tides, CO-OPS verifies TCARI grids and observed water levels at the conclusion of each survey.

### C.3.2.2 Optical Level Data

Optical level data was not acquired.

## C.4 Vessel Positioning

**Data Acquisition Methods and Procedures**

As described in Section A.5 of this document.

**Data Processing Methods and Procedures**

As described in Section C.3 of this document.

## C.5 Sound Speed

### C.5.1 Sound Speed Profiles

**Data Acquisition Methods and Procedures**

S222 uses an AML Micro CTD Probe installed inside an MVP free-fall fish to acquire sound speed profiles. Profiles aboard the ship are generally acquired at 30 to 90 minute intervals. Casts are taken at least once every four hours. Cast frequency is increased when the comparisons show significant variability. Casts are generally taken no more frequently than once every 15 minutes. Sampling intervals are adjusted to ensure spatial variability or if there is suspicion of sudden changes in the water-column.

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a towfish containing a sound speed sensor. The fish is towed behind the survey vessel in a ready position that is marked by messengers attached to the tow cable. The towfish is typically deployed at a ready depth that is approximately the same depth of the ship MBES transducers. Deployment depth is a function of water depth. The towfish descends at the rate of freefall when deployed. Towfish freefall is automatically stopped once a specified depth limit is met and the drag forces on the fish cause it to rise toward the surface due to the ship's forward motion. The cable slack is then pulled in by the winch to the ready towing position.

HSL 2903 and HSL 2904 both use Sea-Bird SBE 19plus CTDs to collect sound speed profiles. Casts are generally taken at 2-4 hour intervals. Casts are also conducted when changing survey areas or when a change of weather, tide, or current warrant. The launch crew also monitors the real time display of the Reson SVP-70/71 sound velocity probe for significant changes in the surface sound velocity. Casts are typically taken in the  deepest portions of the project area.

The following procedure is followed when conducting manual CTD casts with the SBE 19plus: The instrument is lowered into the water and submerged just below the water's surface for about two minutes to allow air to escape the salinity cell. The instrument is lowered at the rate of free fall. The instrument is lowered slowly through the first 5-10 meters of water in order to accurately sample the sound speed for areas with lenses of fresh water or other complex sound speed variation near the surface.

Pydro Sound Speed Manager software is used to process all CTD data. Each cast is processed immediately after the cast is taken. The cast is checked for obviously erroneous data and then distributed to MBES systems for use in real-time ray-tracing processes.

**Data Processing Methods and Procedures**

Sound Speed Manager (distributed with Pydro) is used to download and process all sound speed data on THOMAS JEFFERSON. Sound speed profiles are visually checked for obviously erroneous data and compared against available historical data. Sound speed cast data is provided to the Kongsberg SIS acquisition program using a data distribution function built into the Sound Speed Manager software.

Processed sound speed data data is applied to the MBES data in Caris HIPS.

### C.5.2 Surface Sound Speed

**Data Acquisition Methods and Procedures**

A Valeport Modus SVS probe is used to measure the speed of sound at the approximate depth of the S222 transducers.

HSL 2903 and HSL 2904 use Reson SV-70/71 probes to acquire sound speed at their respective transducer faces.

Sound speed values are applied in real-time to all MBES systems to provide refraction corrections to flat-faced transducers.

The accuracy of each surface sound speed device is checked against the closest CTD data point after every CTD cast.

**Data Processing Methods and Procedures**

Surface sound speed data are logged directly into both Kongsberg raw data files and raw/processed sound speed files.

Surface sound speed data are not typically processed after the time of acquisition.

## C.6 Uncertainty

### C.6.1 Total Propagated Uncertainty Computation Methods

Total Propagated Uncertainty (TPU) is calculated in Caris HIPS using the 'Compute TPU' tool.

The uncertainty values for each input into the TPU model can come from one of three sources: Real-time, Static, or Vessel. Real-time values are provided from the sensor or processing package (e.g. POSPac RMS values). Static values are those entered manually into the Compute TPU dialog (e.g. tidal zoning uncertainty and sound speed measurement uncertainties). Static values are documented in each Descriptive Report. Vessel values are taken from the HVF if no realtime or static values are available.

Uncertainty values entered into the HVF for the multibeam and positioning systems are derived from manufacturer specifications sheets for each sensor and from values set forth in section 4.2.3.8 and Appendix 4 - Caris HVF Uncertainty Values of the 2014 FPM.

Sound speed static values are derived from the guidance in the FPM, manufacturer specifications and annual calibration results.

Tide correction uncertainty values depend on the method of correction: real-time values are used for the TCARI workflow; static values specified in the Project Instructions are used for Zoned Tides or ERS workflows.

Ellipsoid height uncertainty values for ellipsoid measurements derived from the Marinstar service are derived from both manufacturer specifications and empirical observation. Static values are used to account for known discrepancies with the magnitude of the position uncertainty values reported by the POS MV system when utilizing Marinestar correctors.

Ellipsoid height uncertainty values for ellipsoid measurements derived from 5P or IAPPK workflows are applied as real-time values from Applanix RMS files.

Both the Kongsberg and Reson MBES systems provide uncertainty statistics that are recorded in raw MBES files.

All offsets, correctors, and values used in TPU calculation that are stored in the HVF file can be found in the included Appendix Folder, HVF Reports. These HVF Reports are output from the Caris HVF Editor in a plain text document readable anywhere, and include all of the requested values for the DAPR necessary to reproduce an HVF.

See included HVFs for information on vessel uncertainty values.

### C.6.2 Uncertainty Components

As described in section C.6.1 above.

## C.7 Shoreline and Feature Data

### Data Acquisition Methods and Procedures

The following workflow is used to develop and verify features:

- Potentially significant features are initially identified and inspected in Caris HIPS (both MBES and SSS contacts).

- A development area polygon or point feature is exported from Caris HIPS; a line plan is created using HIPS or ArcMap if needed.

- Object Detection level MBES data are collected over all MBES and/or SSS contacts and all possible shoal areas.

Quality of data is controlled through:

- Real time monitoring during acquisition to ensure that all features are covered by near nadir beams.

- Inspection of the resultant CUBE surface's Density, Standard Deviation, and Uncertainty layers.

- All developments are examined for significance. Objects found to be significant are flagged with a designated sounding, and become part of the Final Feature File.

**Data Processing Methods and Procedures**

Feature verification begins during initial data processing. Both SSS and MBES data are processed following the conclusion of daily acquisition operations or at regular intervals (typically daily) for continuous ship operations. Significant contacts are identified and noted during initial processing. All significant contacts are then developed using a MBES. When conducting Multibeam surveys, or when reviewing MBES developments over side scan sonar contacts, the least depths over navigationally significant features are flagged as 'designated soundings', then imported into Caris BASE Editor or HIPS. Inside BASE Editor, each significant contact is given an S-57 attribution, and the hydrographer recommends charting action. The final deliverable is a Final Feature File (FFF) in .000 format.

## C.8 Bottom Sample Data

**Data Acquisition Methods and Procedures**

HSD Operations typically provides the field unit with a number of recommended bottom sample sites. Proposed sample sites are encoded as S-57 SPRINGS and are provided in files distributed with the Project Instructions for the survey.

Bottom sample acquisition typically occurs after the majority of main-scheme MBES acquisition has completed. Bathymetric surfaces, backscatter surfaces and SSS intensity mosaics are examined to confirm the validity of the proposed sample sites. Sample sites may be moved or eliminated depending on field conditions.

Samples are collected by launch or ship using one of the bottom samplers described in the equipment section of this report.

Imagery of the bottom type is collected in accordance with HSSD 2018 requirements.

Physical sample bottom material is discarded after field analysis is complete.

**Data Processing Methods and Procedures**

Samples are analyzed for sediment type and classified with S57 attribution.

The NATSUR S-57 attribute for a sample site is characterized as “unknown” in the event that no sample is obtained after three collection attempts.

S-57 attribution is conducted in Caris HIPS or BASE Editor.

Imagery is included as a feature file media attachment.

All bottom samples are processed in accordance with HSD HTD 2018-4_Bottom Sample Drop Camera Imagery.

# D Data Quality Management

## D.1 Bathymetric Data Integrity and Quality Management

### D.1.1 Directed Editing

All statistics layers generated by the Caris CUBE implementation are used (including uncertainty, hypothesis count, hypothesis strength, and standard deviation) to direct data cleaning.

The Flier Finder function in Pydro QC Tools is used to direct cleaning of potential 'fliers' in the bathymetric surface data.

### D.1.2 Designated Sounding Selection

In accordance with HSSD.

### D.1.3 Holiday Identification

Holidays are identified primarily through the use of two tools: the QC Tools program included with the Pydro software program and via standard tools included in ArcGIS (primarily to inspect SSS mosaics). All surfaces are also visually inspected.

### D.1.4 Uncertainty Assessment

In accordance with HSSD using methods described above.

### D.1.5 Surface Difference Review

#### D.1.5.1 Crossline to Mainscheme

Difference surfaces are conducted in accordance with HSSD and as outlined in the DR.

#### D.1.5.2 Junctions

Difference surfaces are conducted in accordance with HSSD and as outlined in the DR.

#### D.1.5.3 Platform to Platform

Difference surfaces are conducted in accordance with HSSD and as outlined in the DR.

## D.2 Imagery data Integrity and Quality Management

### D.2.1 Coverage Assessment

Coverage is assessed in accordance with HSSD.

Automated and visual methods are used to inspect surface coverage: ArcGIS tools are used to automatically identify coverage deficiencies; surfaces are inspected against brightly colored backgrounds for visible gaps in coverage.

CUBE statistical surfaces that show gridded node density are used to visually assess surfaces for compliance with bathymetric surface node density requirements.

Pydro QC Tools is used to statistically inspect CUBE surfaces for compliance with bathymetric surface node density requirements.

### D.2.2 Contact Selection Methodology

Contacts are selected in accordance with HSSD.

Visual inspection of all SSS data is conducted in Caris HIPS by multiple scanners (initial processor, check scanner and/or sheet manager).

# List of Appendices:

| ***Mandatory Report*** | ***File*** |
|---|---|
| *Vessel Wiring Diagram* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| *Sound Speed Sensor Calibration* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| *Vessel Offset* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| *Position and Attitude Sensor Calibration* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| *Echosounder Confidence Check* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| *Echosounder Acceptance Trial Results* | OPR-D304-TJ-18_DAPR_Appendices.pdf |

| ***Additional Report*** | ***File*** |
|---|---|
| *HVF Values* | OPR-D304-TJ-18_DAPR_Appendices.pdf |
| ***Additional Report*** | ***File*** |
| *HSRR Documentation* | OPR-D304-TJ-18_DAPR_Appendices.pdf |

## E. Approval Sheet

As Chief of Party, I have ensured that standard field surveying and processing procedures were adhered to during these projects in accordance with the Hydrographic Surveys Specifications and Deliverables (2018 ed).

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

| Approver Name | Approver Title | Date | Signature |
|---|---|---|---|
| LT Charles Wisotzkey | Acting Field Operations Officer | 07/17/2018 | |
| CDR Chris van Westendorp | Commanding Officer | 07/17/2018 | |

# Appendix 1:

# Vessel wiring diagrams

Updated: 6/5/2018

# Appendix 1:

# Vessel wiring diagrams

Vessel wiring diagrams are not included with this report for reasons related to IT security. Please contact the field unit for specific concerns related to the integration setup used on survey platforms.

# Appendix 2:

# Sound speed calibration reports

Updated: 6/5/2018

# Certificate of Calibration

| | |
|---|---|
| Customer: | NOAA, Group : NOAA Office of Marine and Aviation Operations (OM |
| Asset Serial Number: | 305387 |
| Asset Product Type: | P•Xchange™ Calibrated Sensor, 1000 dBar |
| Calibration Type: | Pressure |
| Calibration Range: | 1000 dBar |
| Calibration RMS Error: | .2112 |
| Calibration ID: | 305387 999999 305387 310717 142025 |
| Installed On: | 009001 |

---

| | | | |
|---|---|---|---|
| Coefficient A: | -1.250149E+2 | Coefficient H: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient I: | -1.702706E-9 |
| Coefficient C: | 0.000000E+0 | Coefficient J: | 0.000000E+0 |
| Coefficient D: | 0.000000E+0 | Coefficient K: | 0.000000E+0 |
| Coefficient E: | 1.917613E-2 | Coefficient L: | 0.000000E+0 |
| Coefficient F: | 0.000000E+0 | Coefficient M: | -6.362273E-16 |
| Coefficient G: | 0.000000E+0 | Coefficient N: | 0.000000E+0 |

Calibration Date (dd/mm/yyyy): 31/7/2017

Certified By:

AML Oceanographic

Robert Haydock

President, AML Oceanographic

AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. Please note that Xchange™ sensor-heads may be installed on assets other than the one listed above; this calibration certificate will still be valid when used on other such assets. If this instrument or sensor has been recalibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary. Older generation instruments may require configuration files, which are available for download at our Customer Centre at www.AMLoceanographic.com/support

AML Oceanographic
2071 Malaview Avenue, Sidney B.C. V8L 5X6 CANADA
T: +1-250-656-0771 F: +1-250-655-3655 Email: service@AMLoceanographic.com

# Certificate of Calibration

| | |
|---|---|
| Asset Serial Number: | 008613 |
| Calibration Type: | Conductivity |
| Certification Date: | February 05, 2018 |
| Sensor SN: | 503497 |
| Calibration Range: | 0 to 62 mS/cm |
| Sensor Range: | 0 to 70 mS/cm |
| Residual (RMSE): | 0.006 mS/cm |
| Standards: | Hart 1560\3529, Autosal 59251 |

### Coefficients

| | | | |
|---|---|---|---|
| Coefficient A: | -1.050911E-2 | Coefficient H: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient I: | 0.000000E+0 |
| Coefficient C: | 0.000000E+0 | Coefficient J: | 0.000000E+0 |
| Coefficient D: | 0.000000E+0 | Coefficient K: | 0.000000E+0 |
| Coefficient E: | 3.297036E-5 | Coefficient L: | 0.000000E+0 |
| Coefficient F: | 0.000000E+0 | Coefficient M: | 0.000000E+0 |
| Coefficient G: | 0.000000E+0 | Coefficient N: | 0.000000E+0 |

AML Oceanographic

**Robert Haydock**
**President, AML Oceanographic**

*AML Oceanographic certifies that the asset described above has been calibrated or recalibrated with equipment referenced to traceable standards. If this instrument or sensor has been re-calibrated, please be sure to update your records. Please also ensure that you update the instrument's coefficient values in any post-processing software that you use, if necessary.*

*AML Oceanographic Ltd. 2071 Malaview Avenue Sidney, B.C. V8L 5X6 CANADA Tel: +1 250-656-0771 Fax: +1 250-655-3655*

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# Certificate of Calibration

| | |
|---|---|
| Asset Serial Number: | 008613 |
| Calibration Type: | Temperature |
| Certification Date: | February 05, 2018 |
| Sensor SN: | 503497 |
| Calibration Range: | 0.7 to 36 ºC |
| Sensor Range: | 0 to +32 ° C |
| Residual (RMSE): | 0.001 ºC |
| Standards: | Hart 1560\3529 |

**Coefficients**

| | | | |
|---|---|---|---|
| Coefficient A: | -1.787242E+1 | Coefficient H: | 0.000000E+0 |
| Coefficient B: | 1.985274E-3 | Coefficient I: | 0.000000E+0 |
| Coefficient C: | -6.663794E-8 | Coefficient J: | 0.000000E+0 |
| Coefficient D: | 2.400537E-12 | Coefficient K: | 0.000000E+0 |
| Coefficient E: | -5.288664E-17 | Coefficient L: | 0.000000E+0 |
| Coefficient F: | 6.452925E-22 | Coefficient M: | 0.000000E+0 |
| Coefficient G: | -3.217359E-27 | Coefficient N: | 0.000000E+0 |



Robert Haydock
President, AML Oceanographic

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*AML Oceanographic Ltd. 2071 Malaview Avenue Sidney, B.C. V8L 5X6 CANADA Tel: +1 250-656-0771 Fax: +1 250-655-3655*

# Certificate of Calibration

| | |
|---|---|
| Asset Serial Number: | 008613 |
| Calibration Type: | Pressure |
| Certification Date: | February 15, 2018 |
| Sensor SN: | 012622 |
| Calibration Range: | 0 to 1001 dBar |
| Sensor Range: | 0 to 1000 dBar |
| Residual (RMSE): | 0.076 dBar |
| Standards: | Paros 785 |

### Coefficients

| | | | |
|---|---|---|---|
| Coefficient A: | -1.237827E+2 | Coefficient H: | 0.000000E+0 |
| Coefficient B: | 0.000000E+0 | Coefficient I: | 3.672845E-9 |
| Coefficient C: | 0.000000E+0 | Coefficient J: | 0.000000E+0 |
| Coefficient D: | 0.000000E+0 | Coefficient K: | 0.000000E+0 |
| Coefficient E: | 1.886383E-2 | Coefficient L: | 0.000000E+0 |
| Coefficient F: | 0.000000E+0 | Coefficient M: | -6.951617E-15 |
| Coefficient G: | 0.000000E+0 | Coefficient N: | 0.000000E+0 |

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President, AML Oceanographic

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# Certificate of Calibration

| | |
|---|---|
| Asset Serial Number: | 004988 |
| Calibration Type: | Pressure |
| Certification Date: | February 14, 2018 |
| Sensor SN: | 0XE111 |
| Calibration Range: | 0 to 1000 dBar |
| Sensor Range: | 0 to 1000 dBar |
| Residual (RMSE): | 0.086 dBar |
| Standards: | Paro 785 |

### Coefficients

| | | | |
|---|---|---|---|
| Coefficient A: | -1.569184E+3 | Coefficient H: | -5.412054E-9 |
| Coefficient B: | -8.337370E-1 | Coefficient I: | 8.407976E-9 |
| Coefficient C: | 2.784933E-3 | Coefficient J: | -2.154370E-11 |
| Coefficient D: | 1.651412E-4 | Coefficient K: | -1.798432E-12 |
| Coefficient E: | 4.769629E-2 | Coefficient L: | 3.779060E-14 |
| Coefficient F: | 2.482477E-5 | Coefficient M: | 0.000000E+0 |
| Coefficient G: | -7.050158E-8 | Coefficient N: | 0.000000E+0 |

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**Robert Haydock**
**President, AML Oceanographic**

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*AML Oceanographic Ltd. 2071 Malaview Avenue Sidney, B.C. V8L 5X6 CANADA Tel: +1 250-656-0771 Fax: +1 250-655-3655*

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# Certificate of Calibration

| | |
|---|---|
| Asset Serial Number: | 004988 |
| Calibration Type: | Sound Velocity |
| Certification Date: | February 21, 2018 |
| Sensor SN: | 139859 |
| Calibration Range: | 1412.0 to 1491 m/s |
| Sensor Range: | 1400 to 1550 m/s |
| Residual (RMSE): | 0.017 m/s |
| Standards: | Micro T 7311 |

### Coefficients

| | | | |
|---|---|---|---|
| Coefficient A: | 1.529685E+3 | Coefficient H: | 0.000000E+0 |
| Coefficient B: | -1.122022E+2 | Coefficient I: | 0.000000E+0 |
| Coefficient C: | 9.128697E+0 | Coefficient J: | 0.000000E+0 |
| Coefficient D: | -8.166249E-1 | Coefficient K: | 0.000000E+0 |
| Coefficient E: | 0.000000E+0 | Coefficient L: | 0.000000E+0 |
| Coefficient F: | 0.000000E+0 | Coefficient M: | 0.000000E+0 |
| Coefficient G: | 0.000000E+0 | Coefficient N: | 0.000000E+0 |

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**President, AML Oceanographic**

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*AML Oceanographic Ltd. 2071 Malaview Avenue Sidney, B.C. V8L 5X6 CANADA Tel: +1 250-656-0771 Fax: +1 250-655-3655*

SonTek
a xylem brand

9940 Summers Ridge Road
San Diego, CA 92121
Tel: (858) 546-8327
support@sontek.com

# CALIBRATION CERTIFICATE

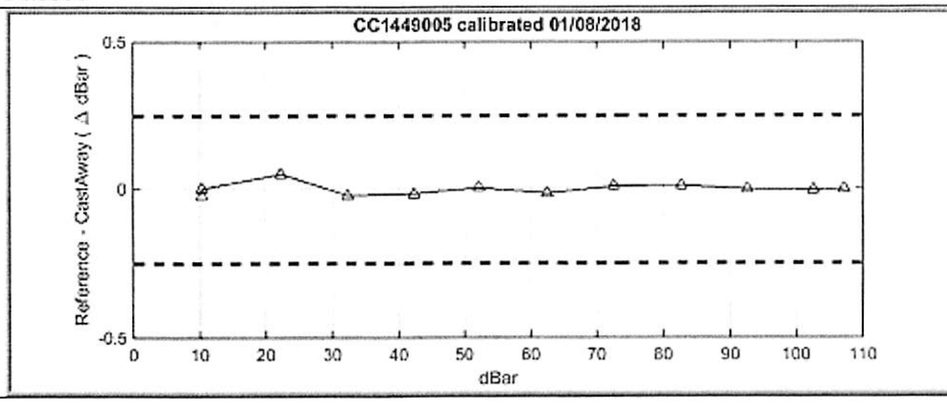
## SYSTEM INFO

| | |
|---|---|
| System Type | CastAway-CTD |
| Serial Number | CC1449005 |
| Firmware Version | 1.60 |
| Date | 01/10/2018 |

## POWER CONSUMPTION

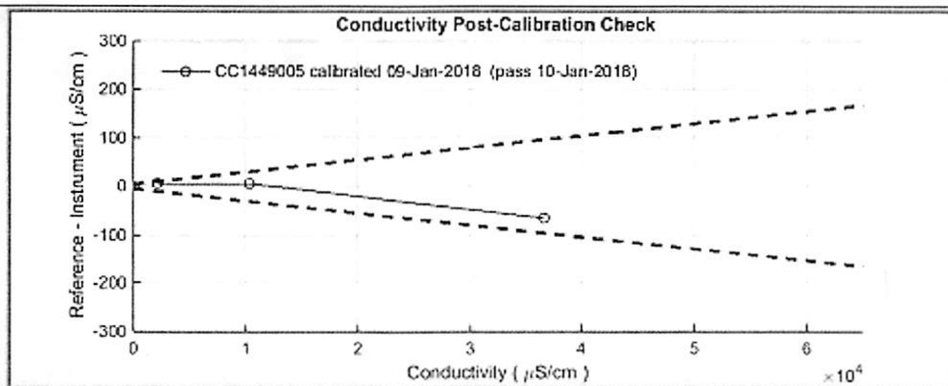
| | |
|---|---|
| Standby Mode (A) | 0.2101 / PASS |
| Supply Voltage | 2.9V |

## CALIBRATION

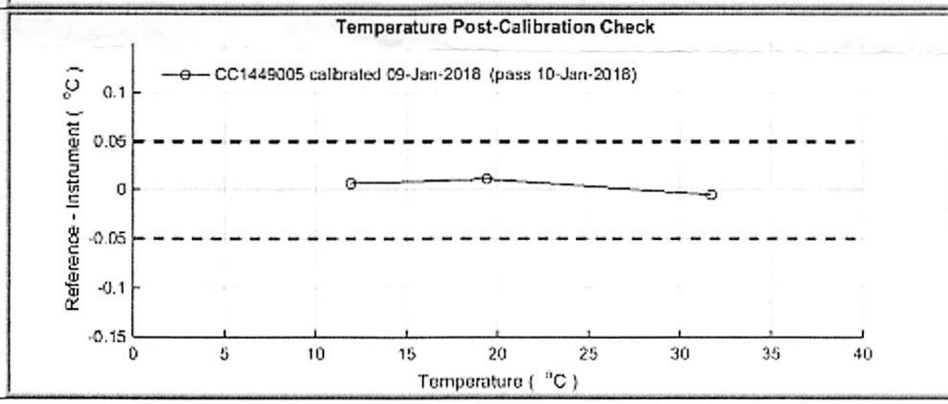
| | |
|---|---|
| GPS | Passed |
| Pressure |   |

a xylem brand
9949 Summers Ridge Road • San Diego, CA 92121 • Telephone (858) 546-8327 • Fax (858) 546-8150 • Internet: www.sontek.com

Conductivity




Temperature




Verified by: Thanh.Nguyen
This report was generated on: 01/11/18

ATTENTION: New Warranty Terms as of March 4, 2013:

This system is covered under a two year limited warranty that extends to all parts and labor for any malfunction due to workmanship or errors in the manufacturing process. The warranty is valid only if you properly maintain and operate this system under normal use as outlined in the User's Manual. The warranty does not cover shortcomings that are due to the design, or any incidental damages as a result of errors in the measurements.

SonTek will repair and/or replace, at its sole option, any product established to be defective with a product of like type. CLAIMS FOR LABOR COSTS AND/OR OTHER CHARGES RESULTING FROM THE USE OF SonTek GOODS AND/OR PRODUCTS ARE NOT COVERED BY THIS LIMITED WARRANTY.

SonTek DISCLAIMS ALL EXPRESS WARRANTIES OTHER THAN THOSE CONTAINED ABOVE AND ALL IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE. SonTek DISCLAIMS AND WILL NOT BE LIABLE, UNDER ANY CIRCUMSTANCE, IN CONTRACT, TORT OR WARRANTY, FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING BUT NOT LIMITED TO LOST PROFITS, BUSINESS INTERRUPTION LOSSES, LOSS OF GOODWILL, OR LOSS OF BUSINESS OR CUSTOMER RELATIONSHIPS.

If your system is not functioning properly, first try to identify the source of the problem. If additional support is required, we encourage you to contact us immediately. We will work to resolve the problem as quickly as possible.

If the system needs to be returned to the factory, please contact SonTek to obtain a Service Request (SR) number. We reserve the right to refuse receipt of shipments without SRs. We require the system to be shipped back in the original shipping container using the original packing material with all delivery costs covered by the customer (including all taxes and duties). If the system is returned without appropriate packing, the customer will be required to cover the cost of a new packaging crate and material.

The warranty for repairs performed at an authorized SonTek Service Center is one year.

TELEDYNE RESON
Everywhereyoulook™

# SVP Test and Calibration certificate

## Valid for surface use*

| | |
|---|---|
| SVP Type : | SVP70 |
| SVP Serial No. | 1013077 |

| | |
|---|---|
| Date of issue : | 5/17/2017 |
| RMA | 527656 |

| | |
|---|---|
| Temperature Calibration : | Fluke Hart 1504 s/n B38892 & Thermistor pn AS115 s/n 3702 |
| Point 1: | 4.5 °C |
| Point 2: | 16.5 °C |
| Point 3: | 25.5 °C |

| | RMS Speed of Sound Errors |
|---|---|
| Temperature Validation : | 0.0331 m/s |

**Calibration & Final Function Test :** Sign : ______

**QA Signature :** Inits : ______

* Surface use: 0 to 20m water depth.

TELEDYNE RESON
Everywhereyoulook™
TELEDYNE-RESON California, USA
Phone: +1 805 964-6260

TELEDYNE RESON
Everywhereyoulook

# SVP Test and Calibration certificate

## Valid for surface use*

| | |
|---|---|
| SVP Type : | SVP70 |
| SVP Serial No. | 0217007 |

| | |
|---|---|
| Date of issue : | 11-01-2018 |

| | |
|---|---|
| Temperature Calibration : | Hart 1504 s/n A6B554 & Thermistor s/n 3014 |
| Point 1: | 4.5 ℃ |
| Point 2: | 16.4 ℃ |
| Point 3: | 25.4 ℃ |

| | |
|---|---|
| | RMS Speed of Sound Errors |
| Temperature Validation : | 0.0119 m/s |

Calibration & Final Function Test : Sign : Find Petersen

QA Signature : Inits : PEJO.

* Surface use: 0 to 20m water depth.

TELEDYNE RESON
Everywhereyoulook
TELEDYNE-RESON A/S, Fabriksvangen 13, DK-3550 Slangerup
Fax: +45 4738 0066, Phone: +45 4738 0022

TELEDYNE RESON
Everywhereyoulook™

# SVP Test and Calibration certificate

## Valid for surface use*

| | | | |
|---|---|---|---|
| SVP Type : | SVP70 | Date of issue : | 2017-02-22 |
| SVP Serial No. | 0614179 | | |

| | |
|---|---|
| Temperature Calibration : | Fluke Hart 1504 s/n B38892 & Thermistor pn AS115 s/n 3702 |
| Point 1: | 4.5 ℃ |
| Point 2: | 16.5 ℃ |
| Point 3: | 25.5 ℃ |

| | RMS Speed of Sound Errors |
|---|---|
| Temperature Validation : | 0.0263 m/s |

Calibration & Final Function Test : Sign : ____________

QA Signature : Inits : ____________

* Surface use: 0 to 20m water depth.

TELEDYNE RESON
Everywhereyoulook™
TELEDYNE-RESON California, USA
Phone: +1 805 964-6260

# Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com


SENSOR SERIAL NUMBER: 0810
CALIBRATION DATE: 11-Aug-16

SBE 19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -4.11206262e+000
h =   4.90916191e-001
i =   1.09409039e-003
j =  -2.89900237e-005
```

```
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

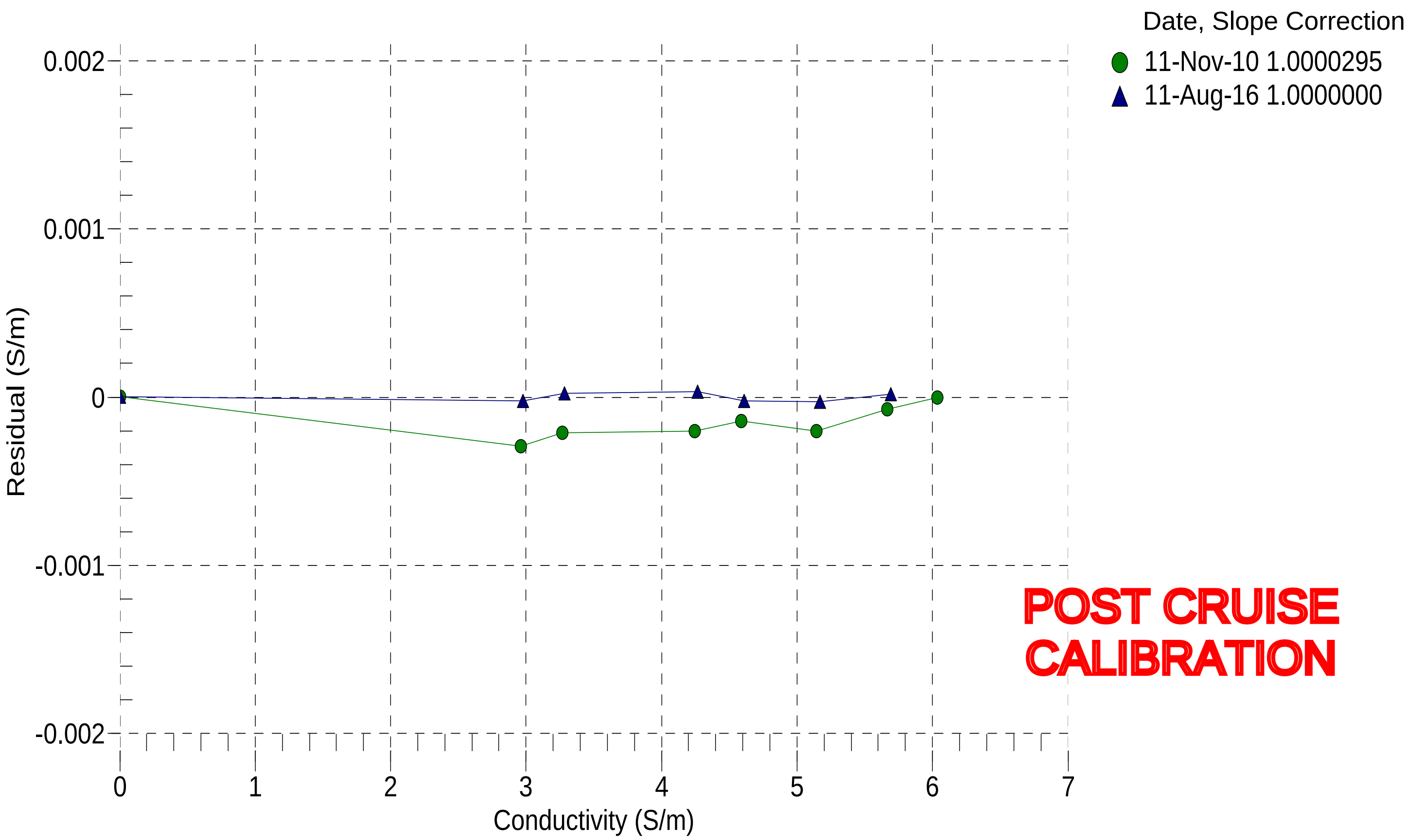
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2.88563 | 0.00000 | 0.00000 |
| 1.0000 | 34.8206 | 2.97630 | 8.24780 | 2.97628 | -0.00002 |
| 4.5000 | 34.8011 | 3.28343 | 8.61178 | 3.28345 | 0.00002 |
| 15.0000 | 34.7590 | 4.26533 | 9.68308 | 4.26536 | 0.00003 |
| 18.5000 | 34.7500 | 4.61052 | 10.03225 | 4.61050 | -0.00002 |
| 24.0001 | 34.7402 | 5.16857 | 10.57224 | 5.16854 | -0.00003 |
| 28.9999 | 34.7351 | 5.69050 | 11.05330 | 5.69052 | 0.00002 |
| 32.4999 | 34.7325 | 6.06302 | 11.38420 | 6.06316 | 0.00014 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity




POST CRUISE CALIBRATION

# Sea-Bird Electronics, Inc.

13431 NE 20th Street, Bellevue, WA 98005-2010 USA

Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com


SENSOR SERIAL NUMBER: 0810
CALIBRATION DATE: 08-Aug-16

SBE 19 PRESSURE CALIBRATION DATA
FSR: 5000 psia S/N 136398 TCV: -221

QUADRATIC COEFFICIENTS:

```
PA0 =     2.506519e+003
PA1 =    -6.498354e-001
PA2 =     3.156054e-008
```

STRAIGHT LINE FIT:

```
M = -6.498198e-001
B =  2.506708e+003
```

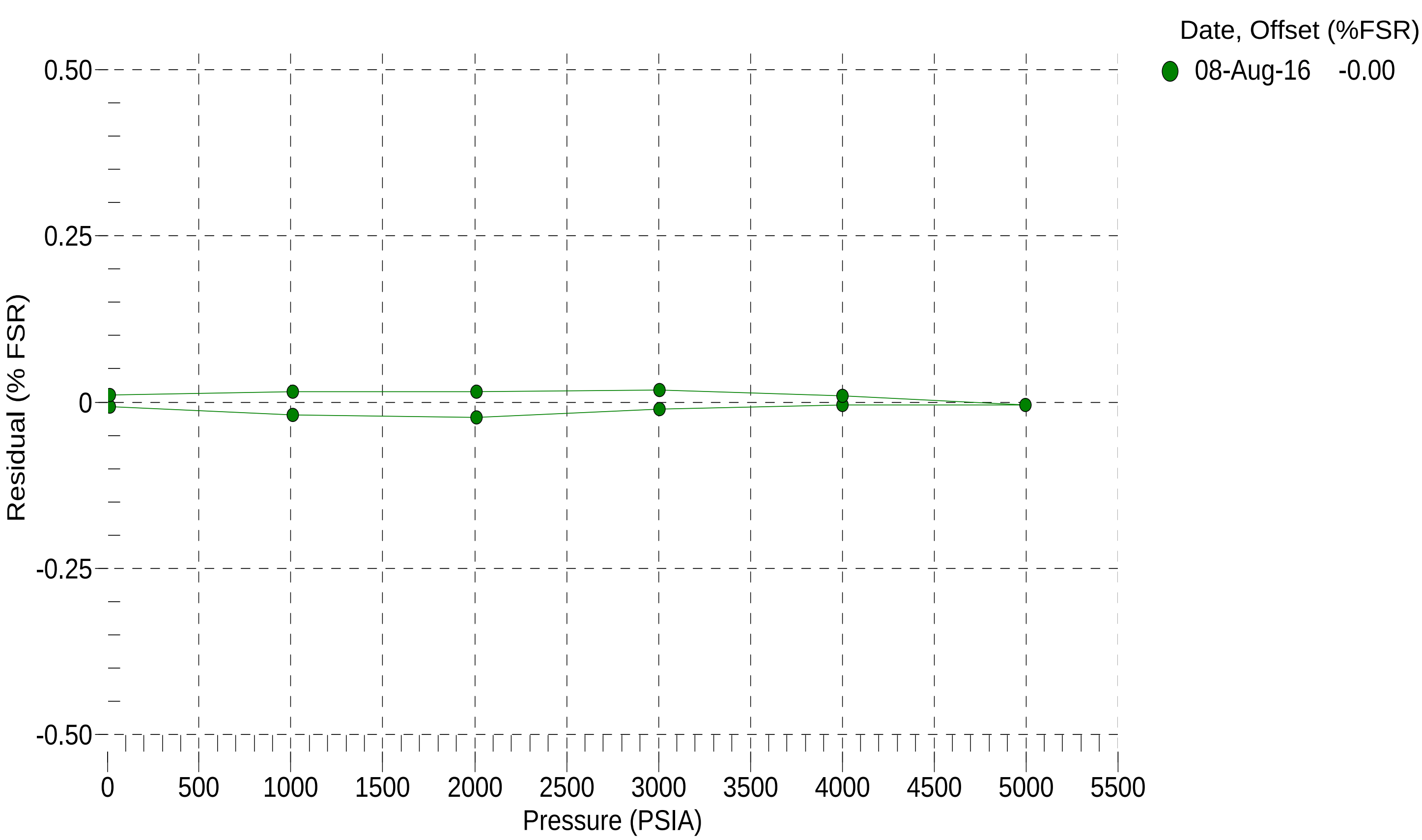
| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) | LINEAR FIT (PSIA) | LINEAR RESIDUAL (%FSR) |
|---|---|---|---|---|---|
| 14.59 | 3835.9 | 14.28 | -0.01 | 14.06 | -0.01 |
| 1011.42 | 2302.5 | 1010.44 | -0.02 | 1010.50 | -0.02 |
| 2008.31 | 768.5 | 2007.14 | -0.02 | 2007.32 | -0.02 |
| 3005.36 | -766.8 | 3004.83 | -0.01 | 3004.99 | -0.01 |
| 4002.24 | -2301.1 | 4002.02 | -0.00 | 4002.01 | -0.00 |
| 4999.20 | -3834.8 | 4998.97 | -0.00 | 4998.64 | -0.01 |
| 4002.27 | -2302.2 | 4002.74 | 0.01 | 4002.72 | 0.01 |
| 3005.47 | -769.2 | 3006.39 | 0.02 | 3006.55 | 0.02 |
| 2008.33 | 765.5 | 2009.09 | 0.02 | 2009.27 | 0.02 |
| 1011.30 | 2300.0 | 1012.06 | 0.02 | 1012.12 | 0.02 |
| 14.60 | 3834.6 | 15.12 | 0.01 | 14.91 | 0.01 |

n = instrument output (counts)

Straight Line Fit: Pressure (PSIA) = M * n + B

Quadratic Fit: Pressure (PSIA) = PA0 + PA1 * n + PA2 * $n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 12-Dec-17

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.977869e-001
h =  1.374792e-001
i = -3.135771e-004
j =  4.190110e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

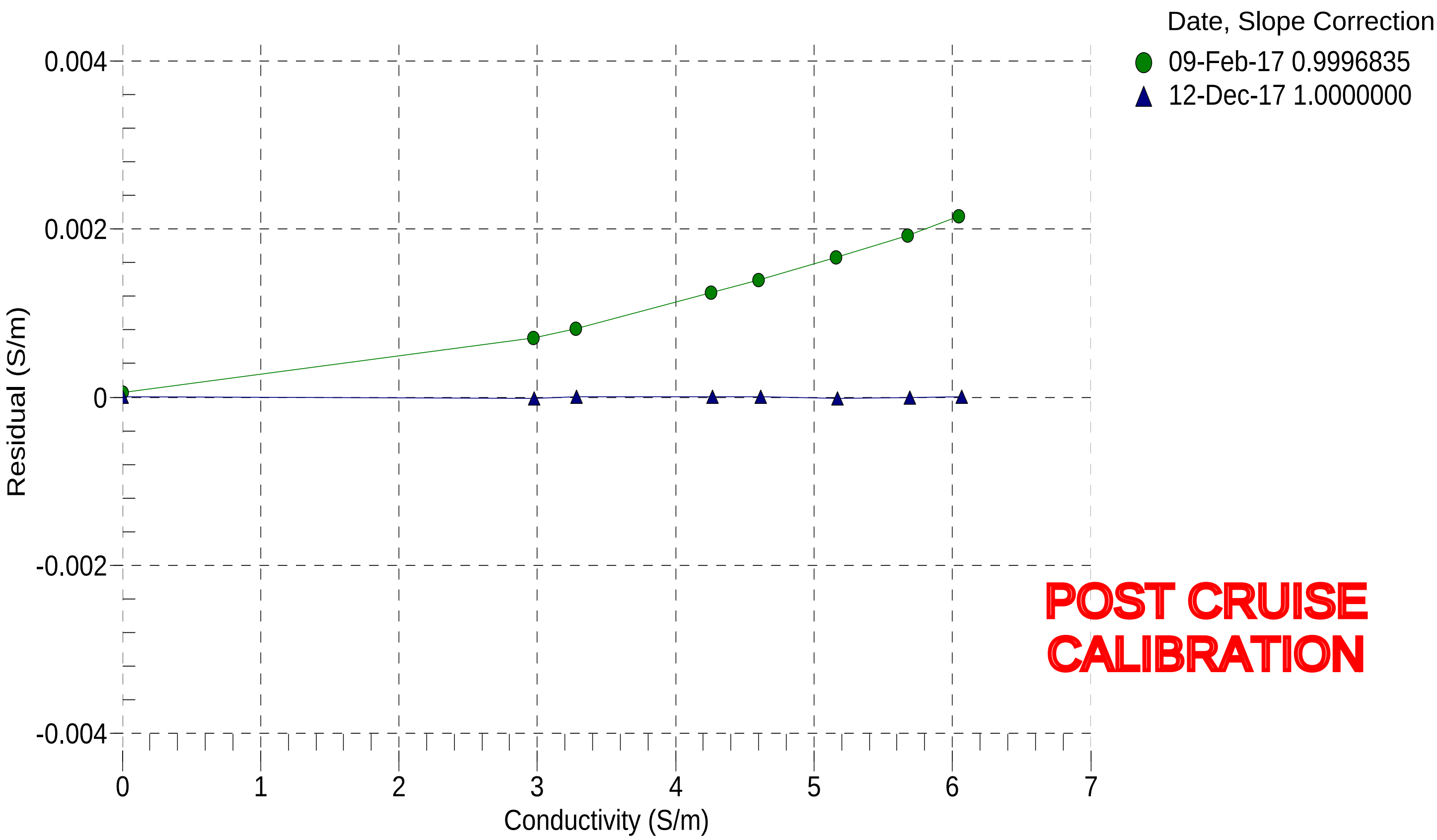
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2699.34 | 0.0000 | 0.00000 |
| 1.0000 | 34.8427 | 2.97801 | 5386.94 | 2.9780 | -0.00001 |
| 4.5000 | 34.8232 | 3.28531 | 5590.68 | 3.2853 | 0.00001 |
| 15.0001 | 34.7813 | 4.26778 | 6196.43 | 4.2678 | 0.00001 |
| 18.5000 | 34.7725 | 4.61319 | 6395.47 | 4.6132 | 0.00000 |
| 24.0000 | 34.7631 | 5.17159 | 6704.43 | 5.1716 | -0.00001 |
| 28.9999 | 34.7581 | 5.69385 | 6980.67 | 5.6938 | -0.00001 |
| 32.4999 | 34.7554 | 6.06656 | 7171.10 | 6.0666 | 0.00001 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



Sea-Bird Scientific
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Bellevue, WA 98005
USA

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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 16-Dec-17

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -1.021594e+000
h =  1.396230e-001
i = -2.363477e-004
j =  3.809685e-005
```

```
CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

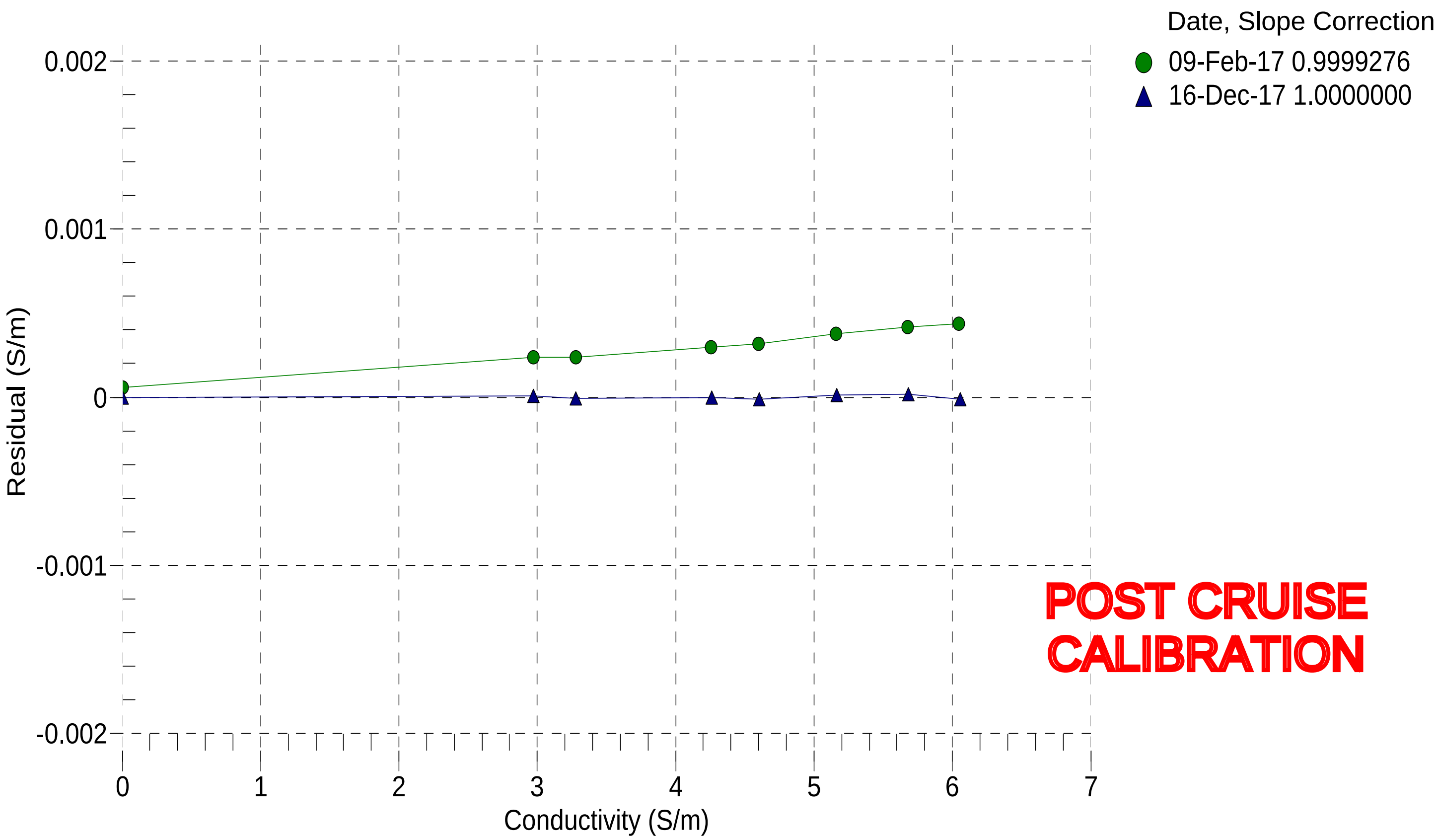
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2708.46 | 0.0000 | 0.00000 |
| 1.0000 | 34.7704 | 2.97242 | 5351.77 | 2.9724 | 0.00001 |
| 4.5000 | 34.7507 | 3.27914 | 5552.77 | 3.2791 | -0.00001 |
| 15.0000 | 34.7088 | 4.25982 | 6150.70 | 4.2598 | -0.00000 |
| 18.5000 | 34.7000 | 4.60460 | 6347.24 | 4.6046 | -0.00001 |
| 24.0000 | 34.6900 | 5.16191 | 6652.37 | 5.1619 | 0.00001 |
| 29.0000 | 34.6839 | 5.68307 | 6925.20 | 5.6831 | 0.00002 |
| 32.5001 | 34.6797 | 6.05487 | 7113.22 | 6.0549 | -0.00001 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 04-Dec-17

SBE 19plus PRESSURE CALIBRATION DATA
1450 psia S/N 2101

COEFFICIENTS:

```
PA0 =       5.940783e-001
PA1 =       4.437308e-003
PA2 =      -2.171621e-011
PTEMPA0 = -8.026650e+001
PTEMPA1 =  4.669965e+001
PTEMPA2 = -2.433074e-001

PTCA0 =  5.211001e+005
PTCA1 =  8.822587e+000
PTCA2 = -1.211043e-001
PTCB0 =  2.480825e+001
PTCB1 = -3.500000e-004
PTCB2 =  0.000000e+000
```

## PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.89 | 524452.3 | 2.2 | 14.88 | -0.00 |
| 300.81 | 588884.5 | 2.2 | 300.78 | -0.00 |
| 588.22 | 653692.8 | 2.2 | 588.15 | -0.00 |
| 875.55 | 718548.8 | 2.2 | 875.56 | 0.00 |
| 1162.92 | 783432.2 | 2.2 | 1162.91 | -0.00 |
| 1450.14 | 848335.9 | 2.2 | 1450.16 | 0.00 |
| 1163.11 | 783472.0 | 2.2 | 1163.08 | -0.00 |
| 875.88 | 718616.7 | 2.2 | 875.86 | -0.00 |
| 588.20 | 653729.9 | 2.2 | 588.32 | 0.01 |
| 300.91 | 588920.3 | 2.2 | 300.93 | 0.00 |
| 14.89 | 524456.2 | 2.2 | 14.90 | 0.00 |

## THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 2.45 | 524532.46 |
| 29.00 | 2.37 | 524549.52 |
| 24.00 | 2.26 | 524530.45 |
| 18.50 | 2.14 | 524502.60 |
| 15.00 | 2.06 | 524484.11 |
| 4.50 | 1.83 | 524418.43 |
| 1.00 | 1.76 | 524395.89 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 24.81 |
| 35.00 | 24.80 |

y = thermistor output (counts)

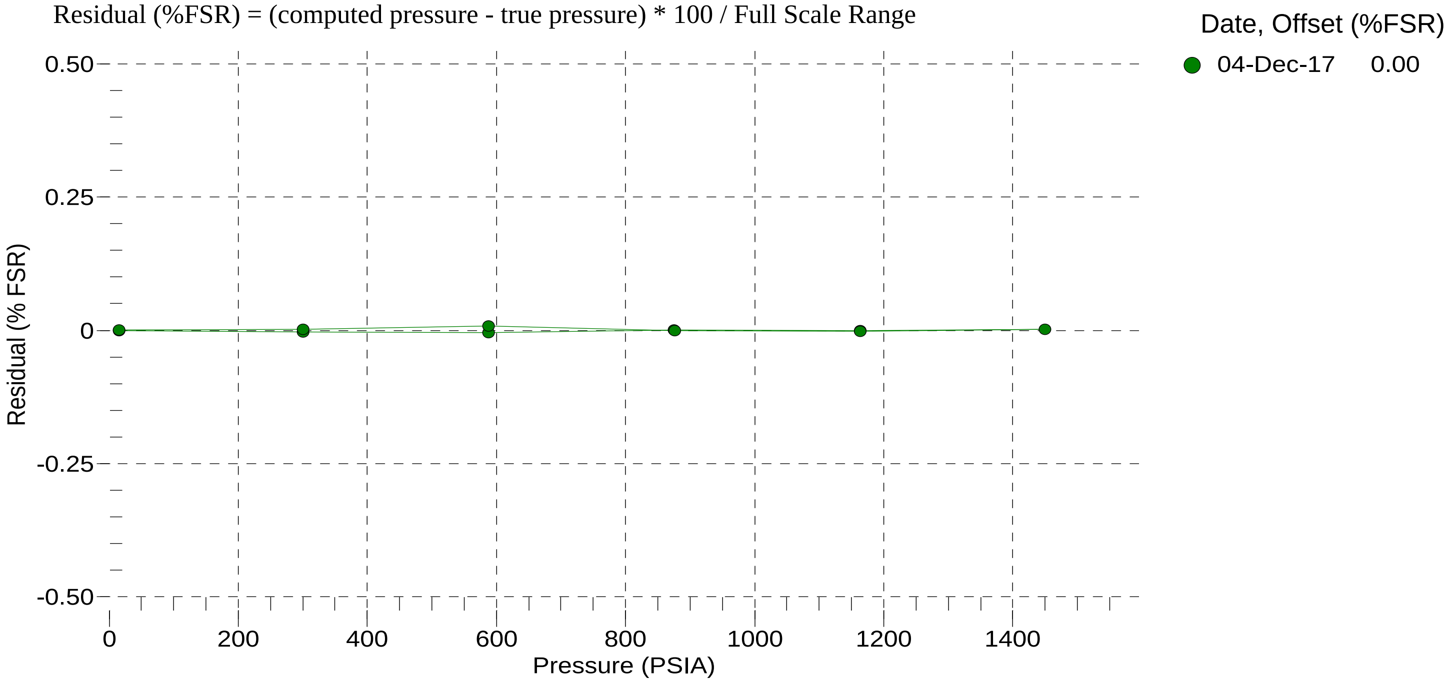
t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * $y^2$

x = instrument output - PTCA0 - PTCA1 * t - PTCA2 * $t^2$

n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * $t^2$)

pressure (PSIA) = PA0 + PA1 * n + PA2 * $n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 11-Dec-17

SBE 19plus PRESSURE CALIBRATION DATA
508 psia S/N 2837

COEFFICIENTS:

| | | | |
|---|---|---|---|
| PA0 = | 7.396059e-002 | PTCA0 = | 5.242489e+005 |
| PA1 = | 1.556819e-003 | PTCA1 = | 4.544278e+000 |
| PA2 = | 6.769618e-012 | PTCA2 = | -1.085417e-001 |
| PTEMPA0 = | -7.395494e+001 | PTCB0 = | 2.498675e+001 |
| PTEMPA1 = | 4.848425e+001 | PTCB1 = | -5.000000e-005 |
| PTEMPA2 = | -2.187811e-001 | PTCB2 = | 0.000000e+000 |

PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.77 | 533741.0 | 2.0 | 14.78 | 0.00 |
| 105.03 | 591688.0 | 2.0 | 105.03 | -0.00 |
| 205.04 | 655855.0 | 2.0 | 205.01 | -0.01 |
| 305.04 | 720001.0 | 2.0 | 305.02 | -0.00 |
| 405.04 | 784107.0 | 2.0 | 405.03 | -0.00 |
| 505.05 | 848182.0 | 2.0 | 505.04 | -0.00 |
| 405.04 | 784134.0 | 2.0 | 405.07 | 0.01 |
| 305.04 | 720029.0 | 2.0 | 305.07 | 0.00 |
| 205.04 | 655883.0 | 2.0 | 205.06 | 0.00 |
| 105.04 | 591704.0 | 2.0 | 105.05 | 0.00 |
| 14.77 | 533733.0 | 2.0 | 14.77 | -0.00 |

THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 2.22 | 533869.31 |
| 29.00 | 2.14 | 533880.39 |
| 24.00 | 2.04 | 533884.65 |
| 18.50 | 1.92 | 533884.17 |
| 15.00 | 1.85 | 533880.95 |
| 4.50 | 1.63 | 533856.20 |
| 1.00 | 1.56 | 533842.36 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 24.99 |
| 35.00 | 24.98 |

y = thermistor output (counts)

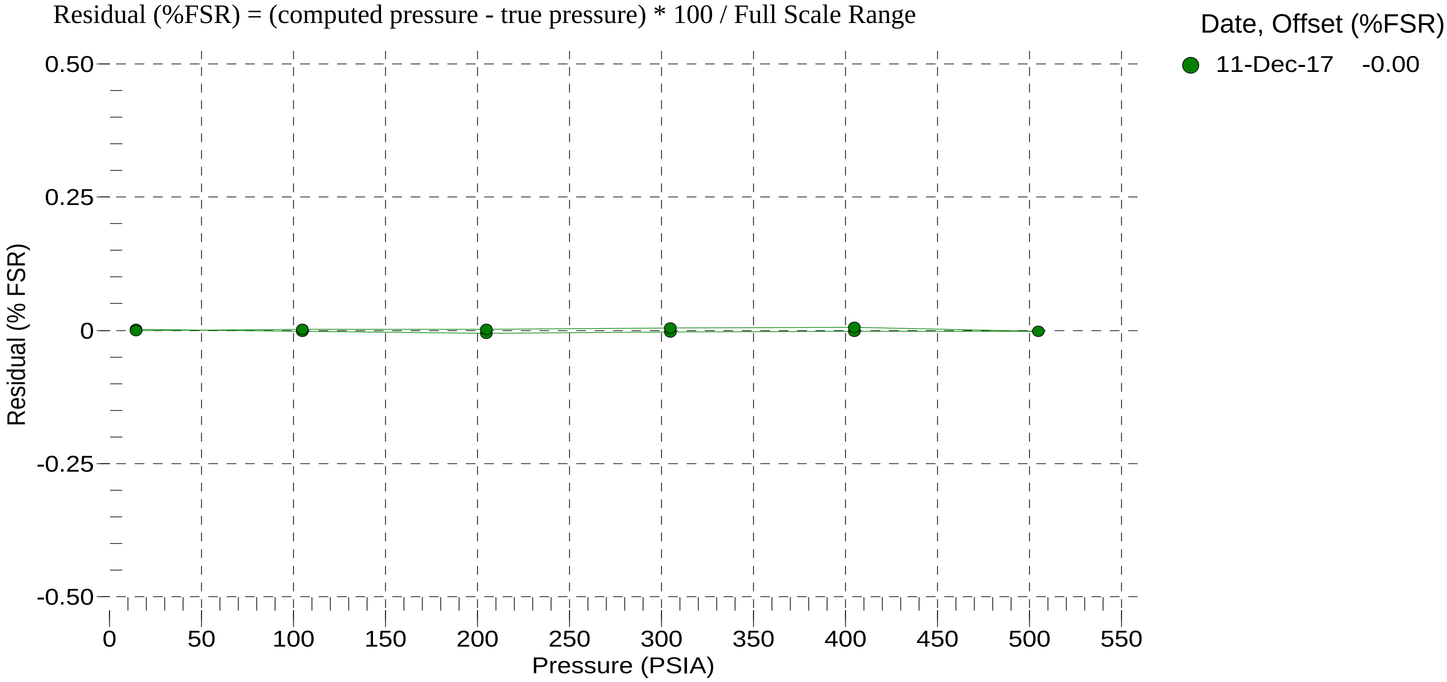
$t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{instrument output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (PSIA)} = PA0 + PA1 * n + PA2 * n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 12-Dec-17

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 =  1.200607e-003
a1 =  2.637963e-004
a2 = -2.405851e-008
a3 =  1.485148e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 693463.034 | 1.0000 | 0.0000 |
| 4.5000 | 619957.695 | 4.5000 | -0.0000 |
| 15.0001 | 434183.271 | 15.0002 | 0.0001 |
| 18.5000 | 383459.932 | 18.4999 | -0.0001 |
| 24.0000 | 313986.288 | 24.0000 | 0.0000 |
| 28.9999 | 260622.847 | 28.9999 | 0.0000 |
| 32.4999 | 228181.254 | 32.4999 | -0.0000 |

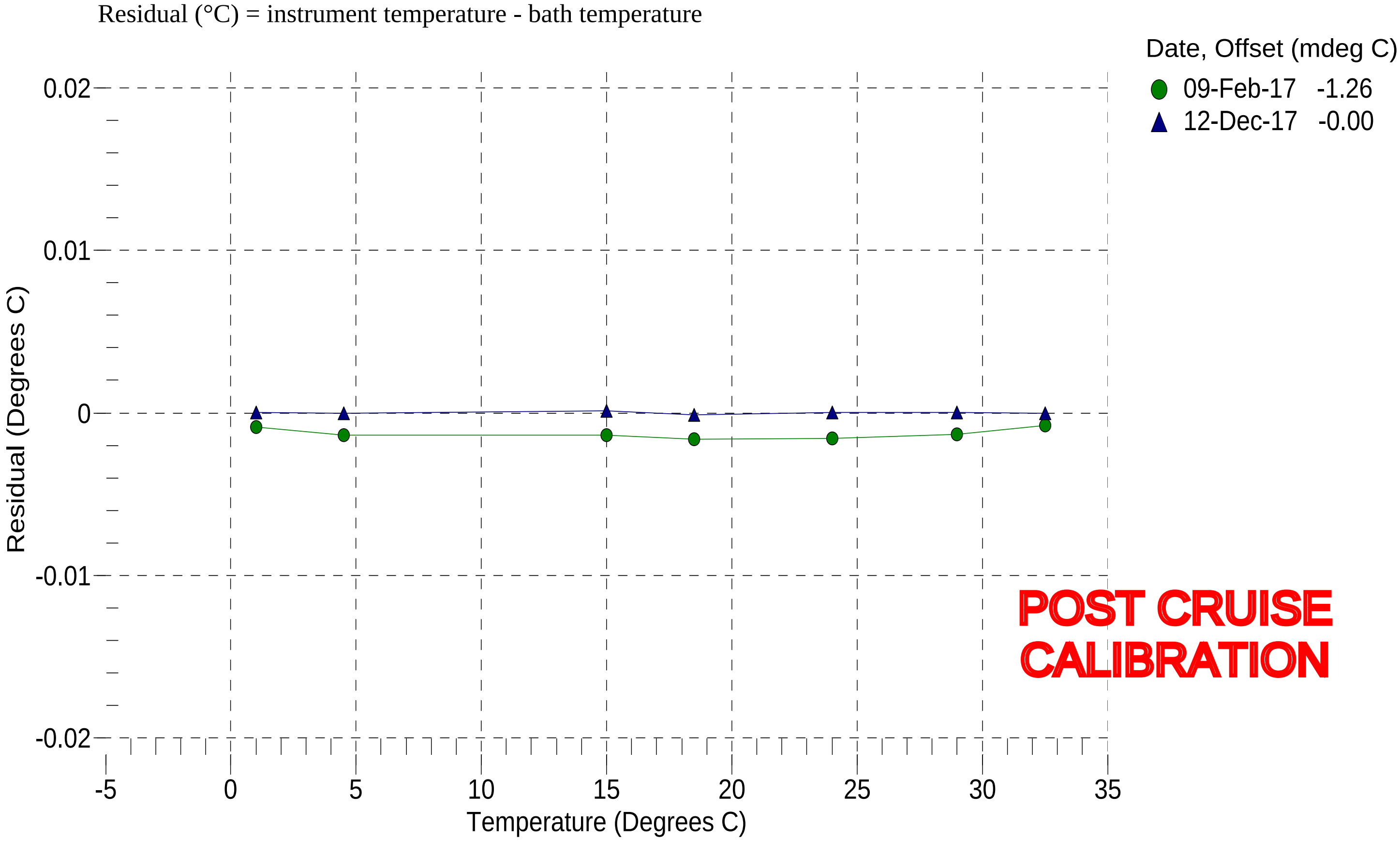
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[\ln(R)] + a2[\ln^2(R)] + a3[\ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 16-Dec-17

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.229836e-003
a1 = 2.552982e-004
a2 = 6.992801e-007
a3 = 1.160010e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 713465.153 | 1.0001 | 0.0001 |
| 4.5000 | 638146.525 | 4.4998 | -0.0002 |
| 15.0000 | 447155.644 | 15.0003 | 0.0003 |
| 18.5000 | 394891.390 | 18.5000 | -0.0000 |
| 24.0000 | 323257.898 | 23.9999 | -0.0001 |
| 29.0000 | 268210.644 | 28.9999 | -0.0001 |
| 32.5001 | 234743.153 | 32.5002 | 0.0001 |

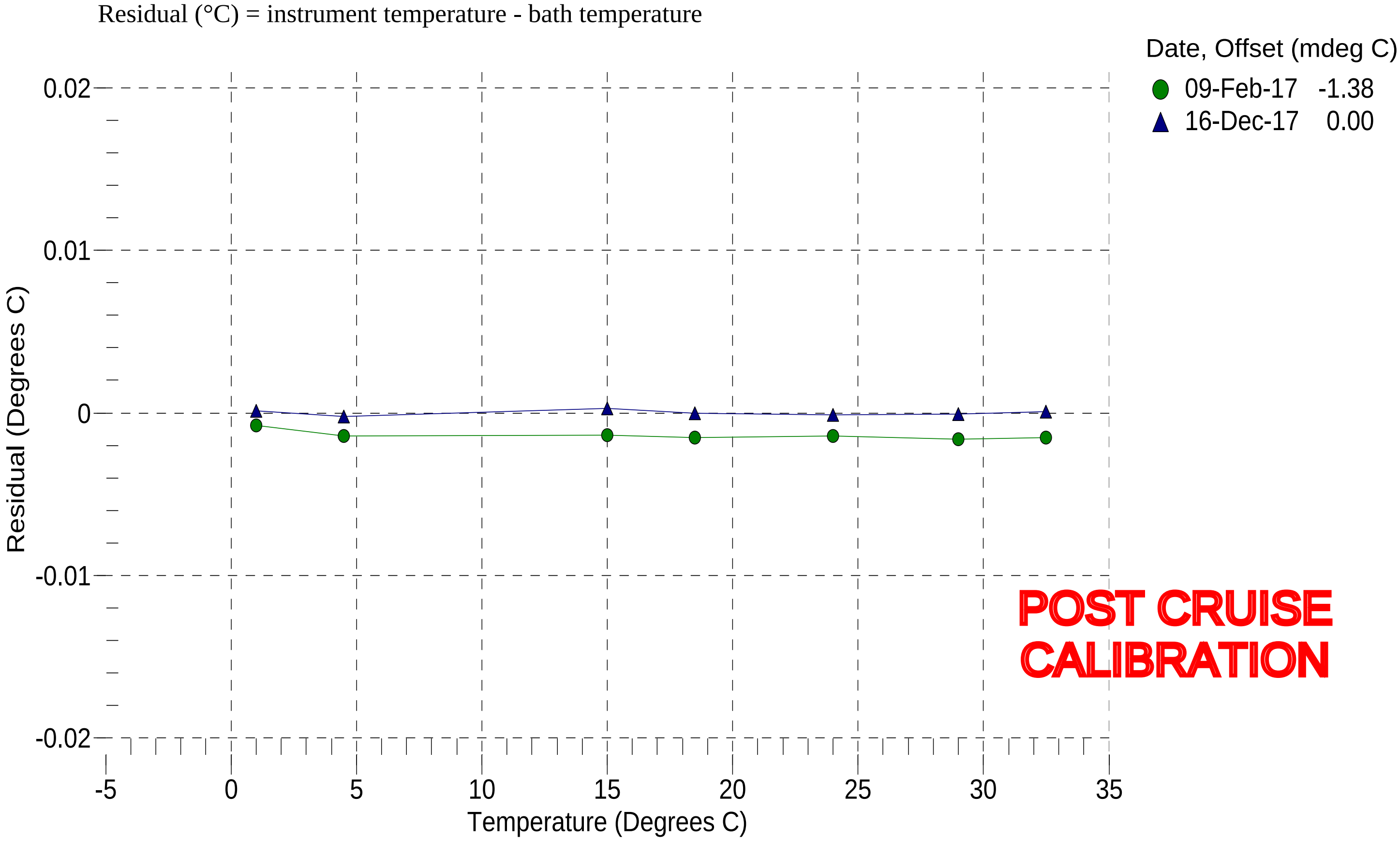
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 07-Dec-17

SBE 19plus V2 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.020276e+000
h = 1.332896e-001
i = 2.482739e-004
j = 1.160830e-006

CPcor = -9.5700e-008
CTcor = 3.2500e-006

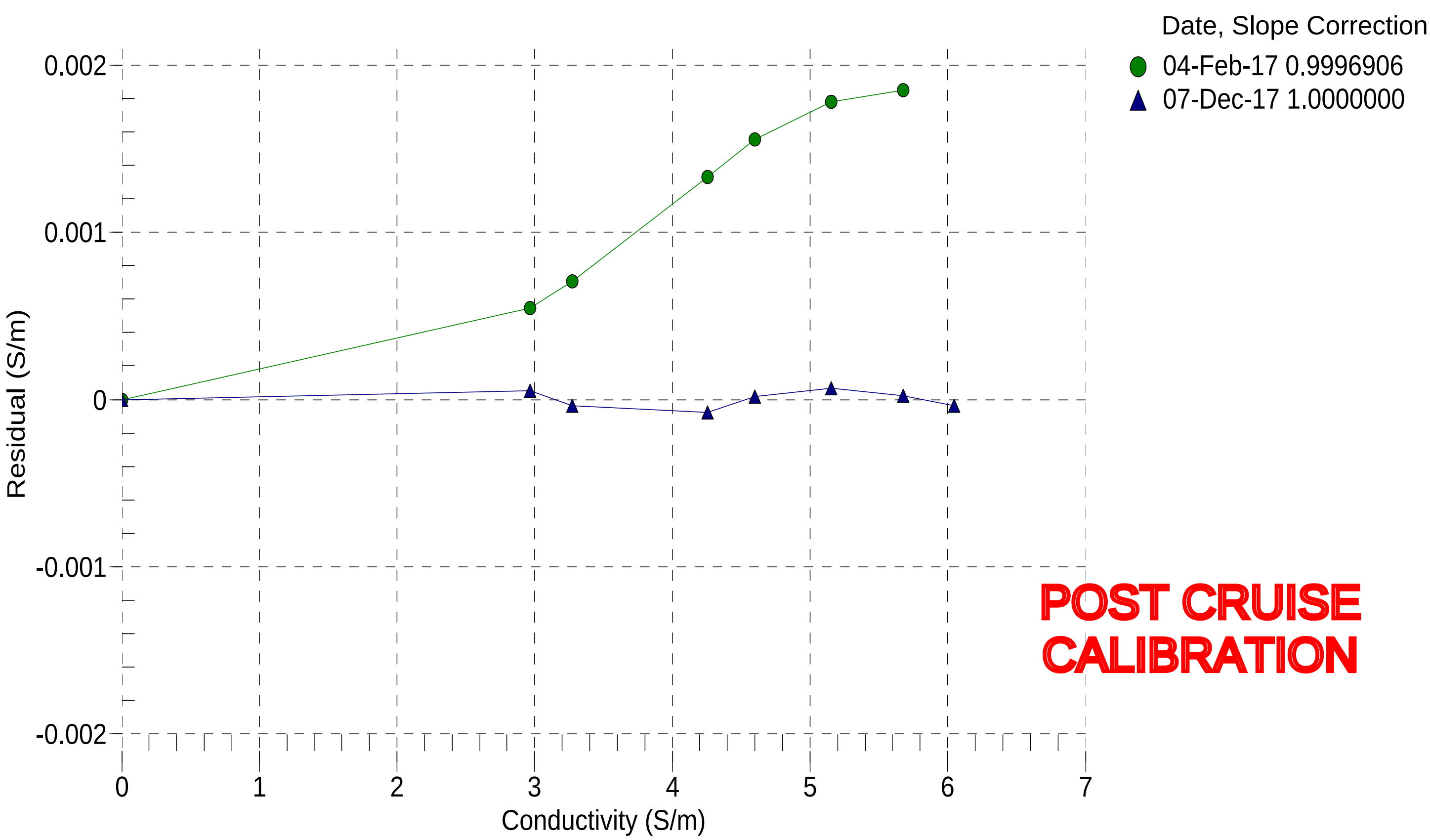
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2759.51 | 0.0000 | 0.00000 |
| 1.0000 | 34.7126 | 2.96794 | 5441.89 | 2.9680 | 0.00005 |
| 4.4999 | 34.6929 | 3.27422 | 5645.82 | 3.2742 | -0.00004 |
| 15.0000 | 34.6511 | 4.25349 | 6252.88 | 4.2534 | -0.00008 |
| 18.4999 | 34.6423 | 4.59776 | 6452.58 | 4.5978 | 0.00002 |
| 24.0000 | 34.6324 | 5.15429 | 6762.66 | 5.1544 | 0.00007 |
| 29.0000 | 34.6264 | 5.67471 | 7040.01 | 5.6747 | 0.00002 |
| 32.5000 | 34.6221 | 6.04594 | 7231.21 | 6.0459 | -0.00004 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity




POST CRUISE CALIBRATION

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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 5-Dec-17

SBE 19plus V2 PRESSURE CALIBRATION DATA
870 psia S/N 3182130

COEFFICIENTS:

| | | | |
|---|---|---|---|
| PA0 = | 1.967040e+000 | PTCA0 = | 5.245776e+005 |
| PA1 = | 2.627831e-003 | PTCA1 = | 5.244279e+001 |
| PA2 = | 2.201140e-011 | PTCA2 = | -8.412054e-001 |
| PTEMPA0 = | -6.484784e+001 | PTCB0 = | 2.523813e+001 |
| PTEMPA1 = | 5.086978e+001 | PTCB1 = | -9.750000e-004 |
| PTEMPA2 = | 1.053404e-002 | PTCB2 = | 0.000000e+000 |

PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.91 | 530236.0 | 1.7 | 14.88 | -0.00 |
| 180.17 | 593017.0 | 1.7 | 180.10 | -0.01 |
| 360.17 | 661346.0 | 1.7 | 360.12 | -0.01 |
| 540.17 | 729601.0 | 1.7 | 540.15 | -0.00 |
| 720.17 | 797774.0 | 1.7 | 720.16 | -0.00 |
| 870.16 | 854514.0 | 1.7 | 870.15 | -0.00 |
| 720.19 | 797793.0 | 1.7 | 720.21 | 0.00 |
| 540.21 | 729639.0 | 1.7 | 540.25 | 0.00 |
| 360.20 | 661391.0 | 1.7 | 360.24 | 0.00 |
| 180.19 | 593067.0 | 1.7 | 180.23 | 0.00 |
| 14.90 | 530260.0 | 1.7 | 14.94 | 0.00 |

THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 1.91 | 530443.20 |
| 29.00 | 1.84 | 530427.40 |
| 24.00 | 1.75 | 530387.98 |
| 18.50 | 1.64 | 530305.39 |
| 15.00 | 1.57 | 530224.25 |
| 4.50 | 1.36 | 529837.37 |
| 1.00 | 1.29 | 529672.01 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 25.24 |
| 35.00 | 25.20 |

y = thermistor output (counts)

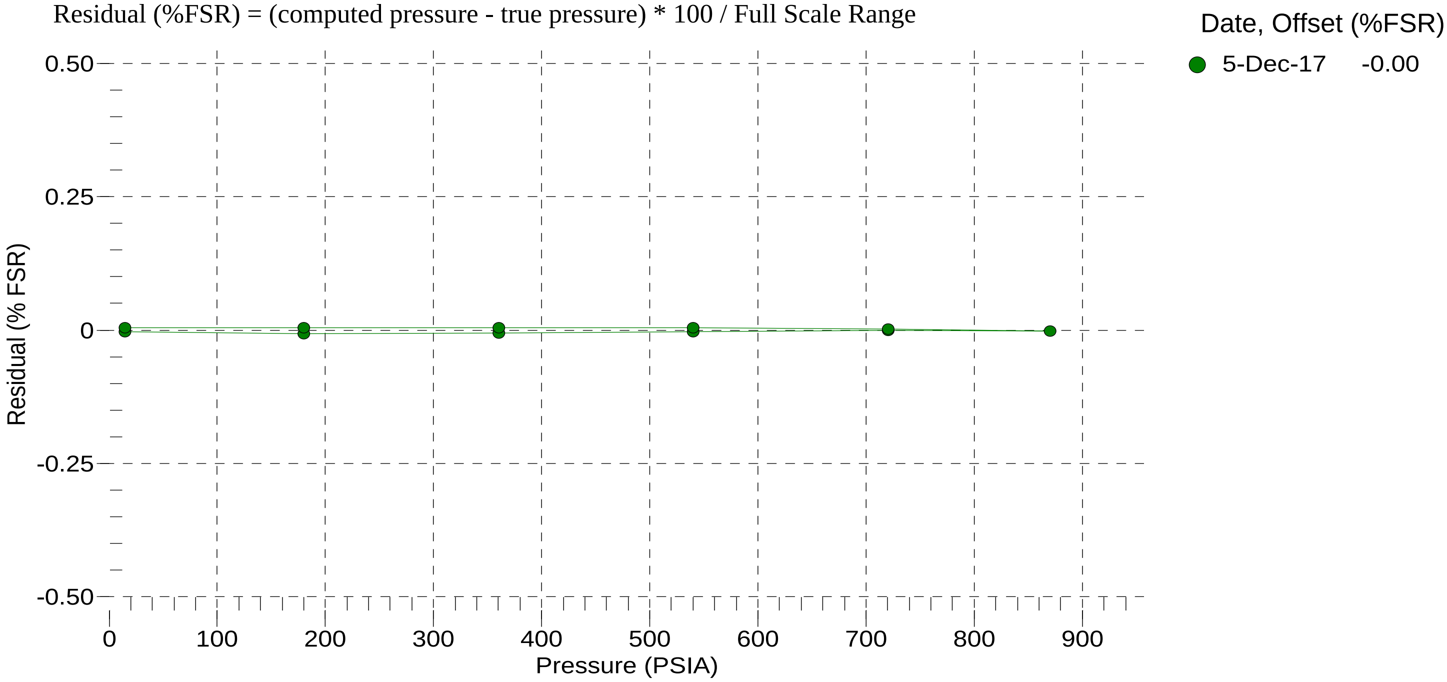
$t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{instrument output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (PSIA)} = PA0 + PA1 * n + PA2 * n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 07-Dec-17

SBE 19plus V2 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.247850e-003
a1 = 2.590230e-004
a2 = -8.049346e-008
a3 = 1.406737e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 702146.102 | 1.0000 | 0.0000 |
| 4.4999 | 626320.780 | 4.4998 | -0.0001 |
| 15.0000 | 435060.661 | 15.0000 | 0.0000 |
| 18.4999 | 383026.458 | 18.4999 | 0.0000 |
| 24.0000 | 311975.356 | 24.0000 | -0.0000 |
| 29.0000 | 257616.051 | 28.9999 | -0.0001 |
| 32.5000 | 224682.169 | 32.5001 | 0.0001 |

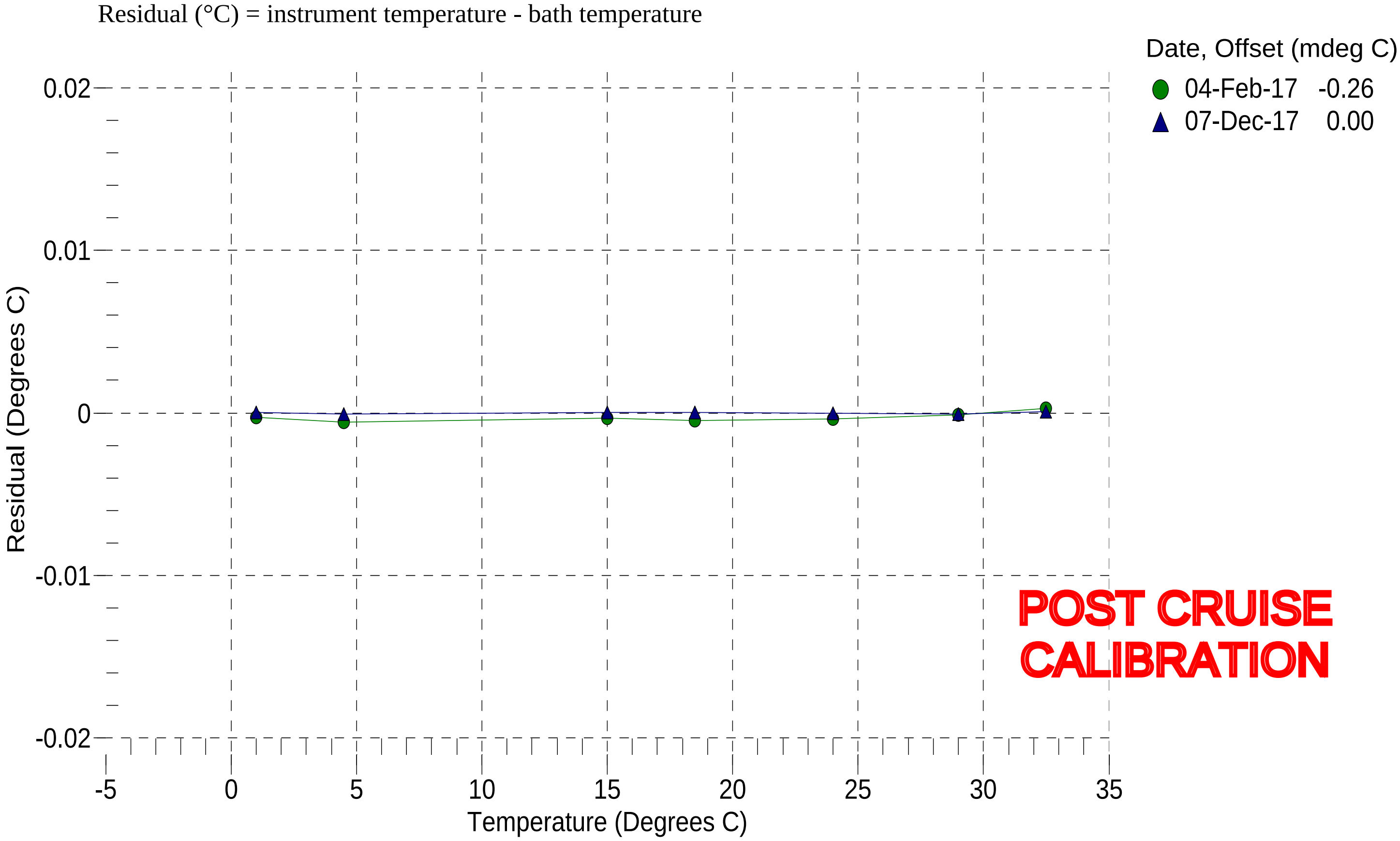
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 19-Dec-17

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.861110e-001
h =  1.720232e-001
i = -4.163156e-004
j =  6.327184e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  2.4322e-007
```

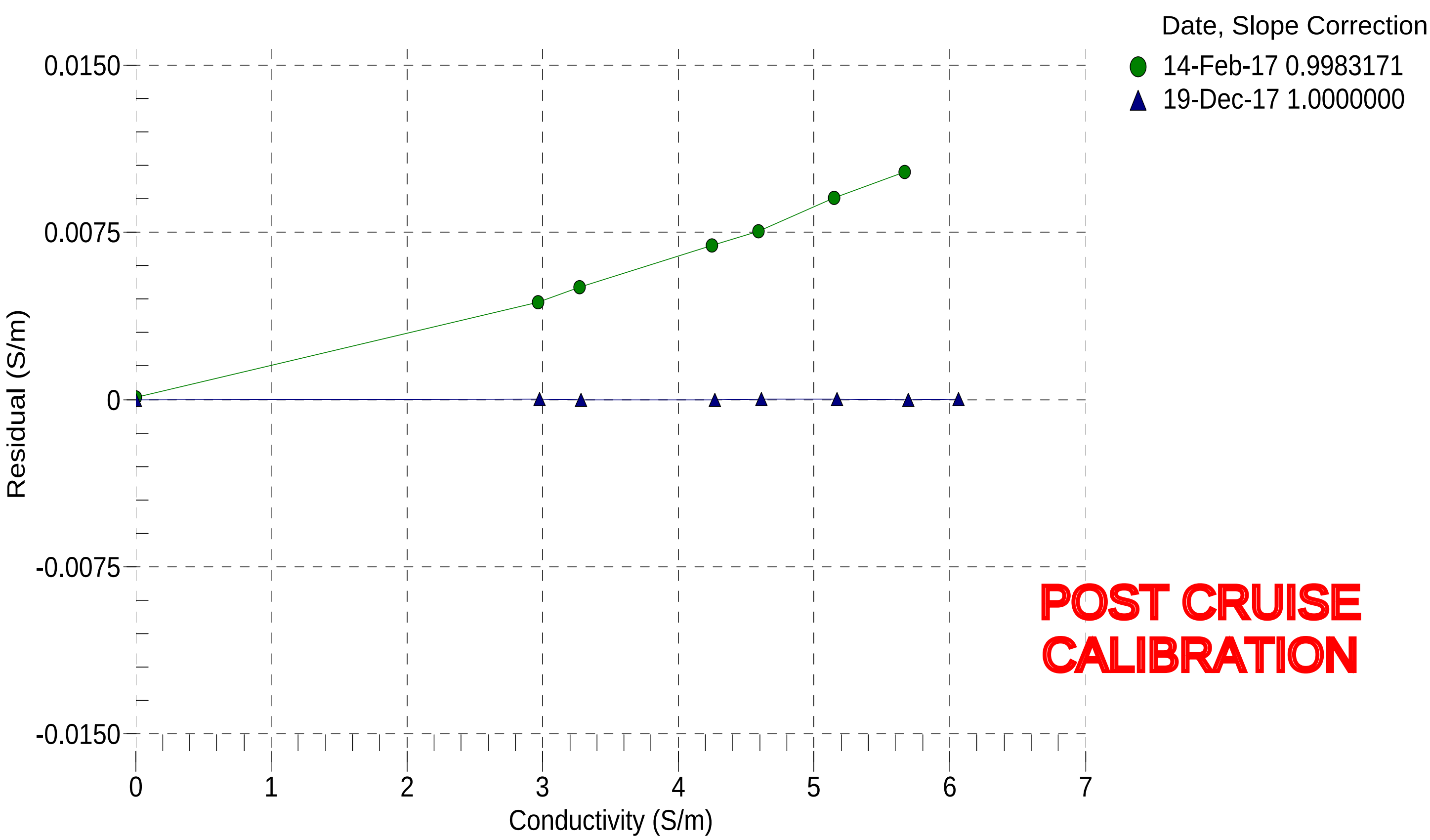
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2398.67 | 0.00000 | 0.00000 |
| 1.0000 | 34.8459 | 2.97825 | 4808.12 | 2.97826 | 0.00001 |
| 4.4999 | 34.8250 | 3.28545 | 4990.41 | 3.28545 | -0.00001 |
| 15.0000 | 34.7808 | 4.26772 | 5532.43 | 4.26772 | -0.00000 |
| 18.4999 | 34.7711 | 4.61301 | 5710.49 | 4.61301 | 0.00000 |
| 24.0000 | 34.7608 | 5.17128 | 5986.90 | 5.17129 | 0.00000 |
| 29.0000 | 34.7553 | 5.69345 | 6234.02 | 5.69344 | -0.00001 |
| 32.5000 | 34.7525 | 6.06612 | 6404.39 | 6.06613 | 0.00000 |

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C);  p = pressure (decibars);  $\delta$ = CTcor;  $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 09-Jan-18

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.835554e-001
h =   1.714970e-001
i =  -3.521082e-004
j =   5.907637e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  2.4322e-007
```

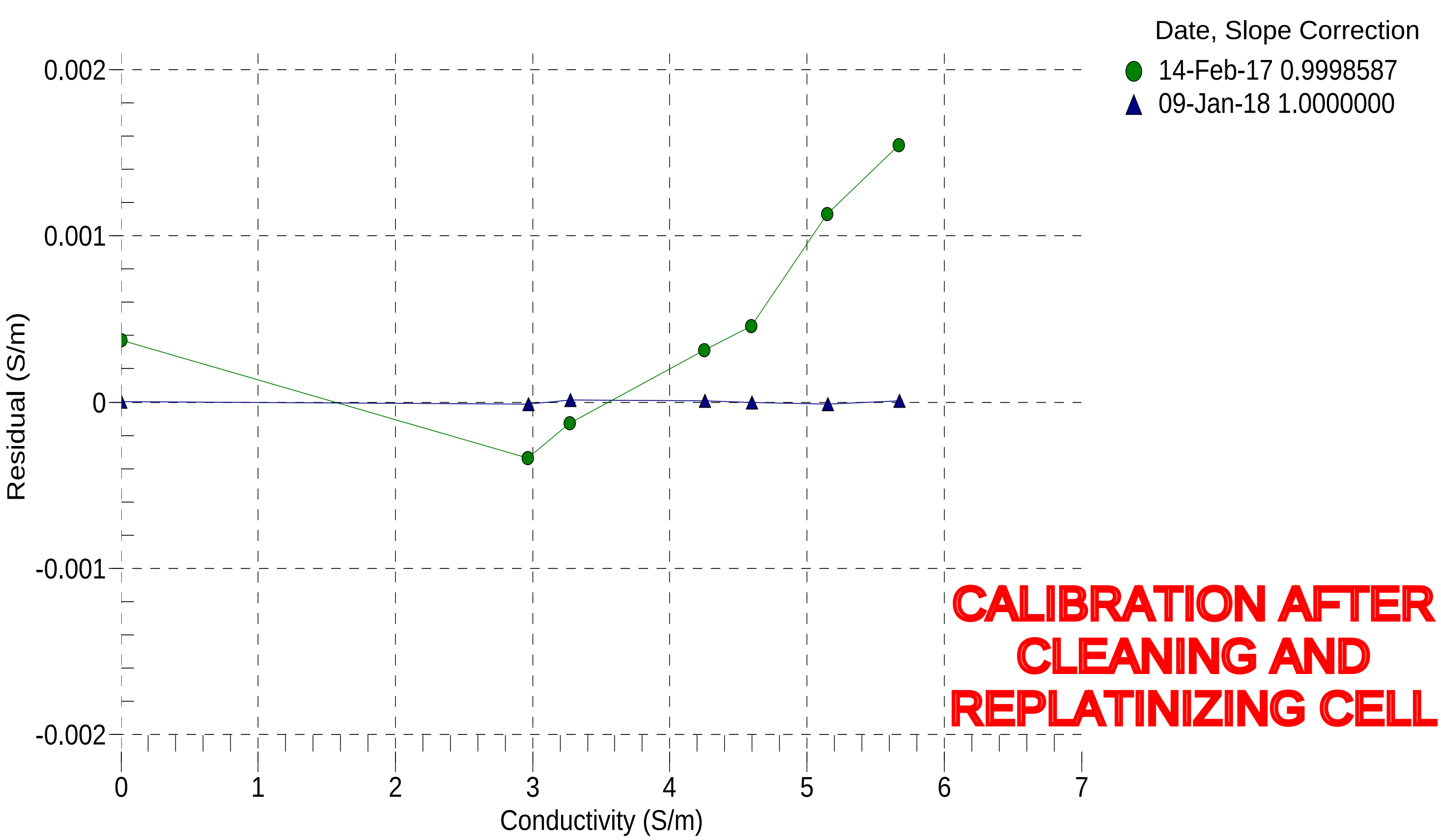
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2398.34 | 0.00000 | 0.00000 |
| 1.0000 | 34.7157 | 2.96818 | 4804.87 | 2.96817 | -0.00001 |
| 4.5000 | 34.6961 | 3.27450 | 4987.05 | 3.27451 | 0.00001 |
| 15.0000 | 34.6543 | 4.25384 | 5528.61 | 4.25384 | 0.00001 |
| 18.5000 | 34.6457 | 4.59817 | 5706.56 | 4.59817 | -0.00000 |
| 24.0000 | 34.6364 | 5.15482 | 5982.75 | 5.15480 | -0.00001 |
| 29.0000 | 34.6310 | 5.67537 | 6229.66 | 5.67538 | 0.00001 |
| 32.5000 | 34.6269 | 6.04669 | 6399.82 | 6.04679 | 0.00010 |

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 19-Dec-17

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

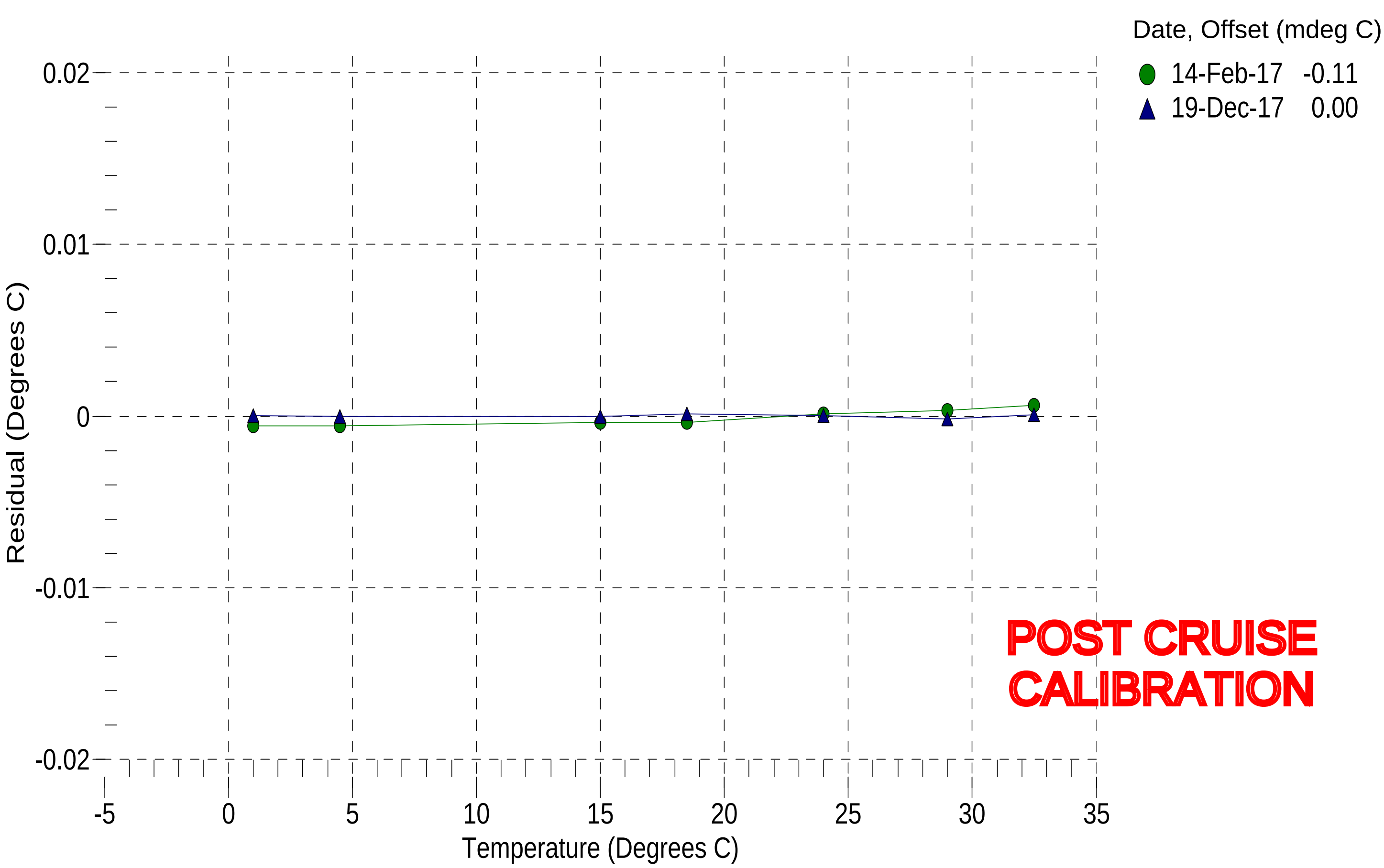
```
a0 =  5.242107e-005
a1 =  2.651814e-004
a2 = -1.805759e-006
a3 =  1.328341e-007
```

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 775027.2 | 1.0000 | 0.0000 |
| 4.4999 | 661001.4 | 4.4999 | -0.0000 |
| 15.0000 | 418251.9 | 15.0000 | -0.0000 |
| 18.4999 | 361334.2 | 18.5000 | 0.0001 |
| 24.0000 | 288860.4 | 24.0000 | 0.0000 |
| 29.0000 | 237121.6 | 28.9998 | -0.0002 |
| 32.5000 | 207212.4 | 32.5001 | 0.0001 |

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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www.seabird.com

SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 09-Jan-18

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

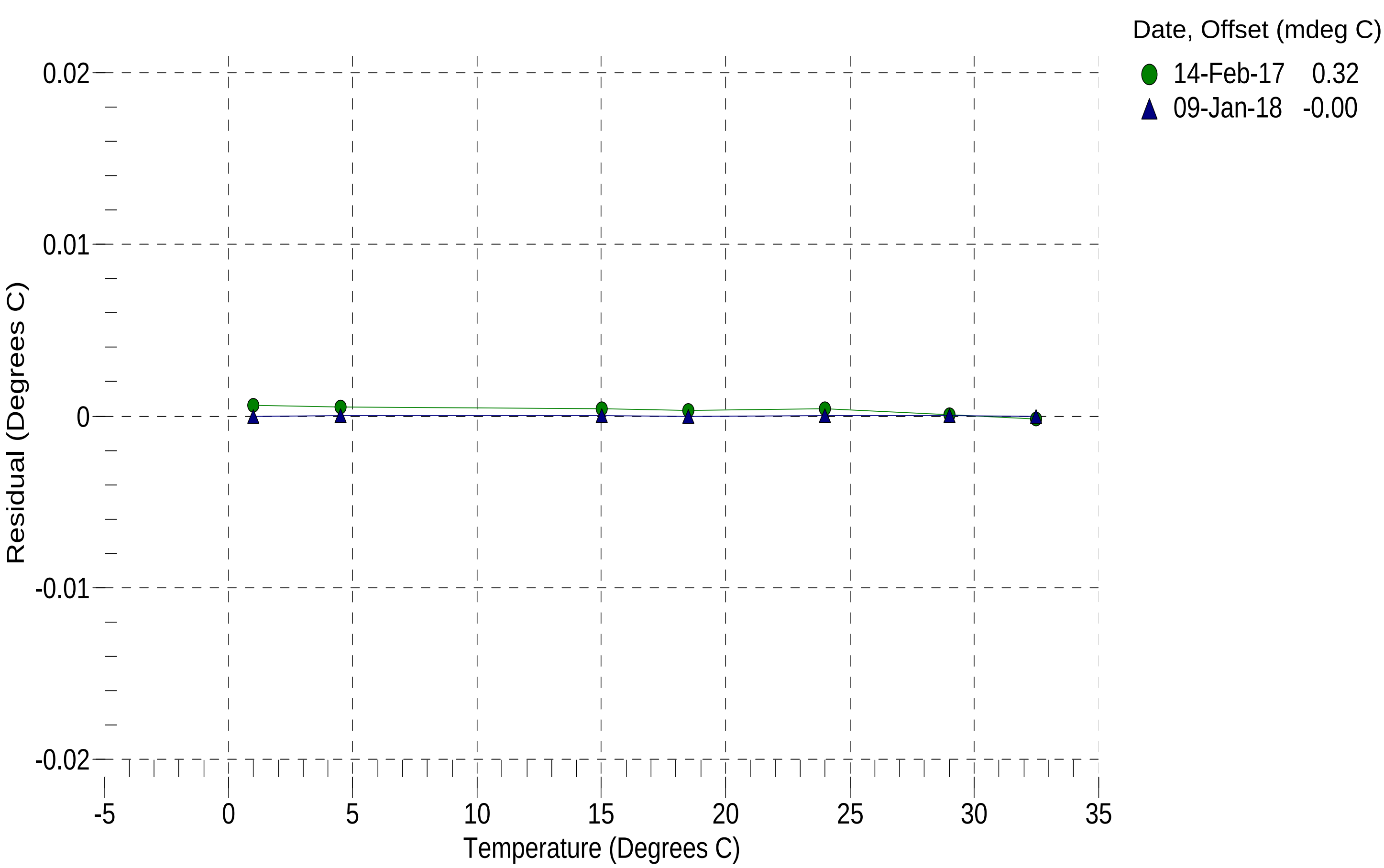
COEFFICIENTS:
a0 = 9.178931e-005
a1 = 2.562145e-004
a2 = -1.124566e-006
a3 = 1.155697e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 775071.2 | 1.0000 | -0.0000 |
| 4.5000 | 661027.7 | 4.5000 | 0.0000 |
| 15.0000 | 418265.2 | 15.0000 | 0.0000 |
| 18.5000 | 361345.2 | 18.5000 | -0.0000 |
| 24.0000 | 288864.2 | 24.0000 | 0.0000 |
| 29.0000 | 237117.5 | 29.0000 | 0.0000 |
| 32.5000 | 207207.0 | 32.5000 | -0.0000 |

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[\ln(n)] + a2[\ln^2(n)] + a3[\ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0810
CALIBRATION DATE: 08-Aug-16

SBE 19 PRESSURE CALIBRATION DATA
FSR: 5000 psia S/N 136398 TCV: -221

QUADRATIC COEFFICIENTS:
PA0 = 2.506519e+003
PA1 = -6.498354e-001
PA2 = 3.156054e-008

STRAIGHT LINE FIT:
M = -6.498198e-001
B = 2.506708e+003

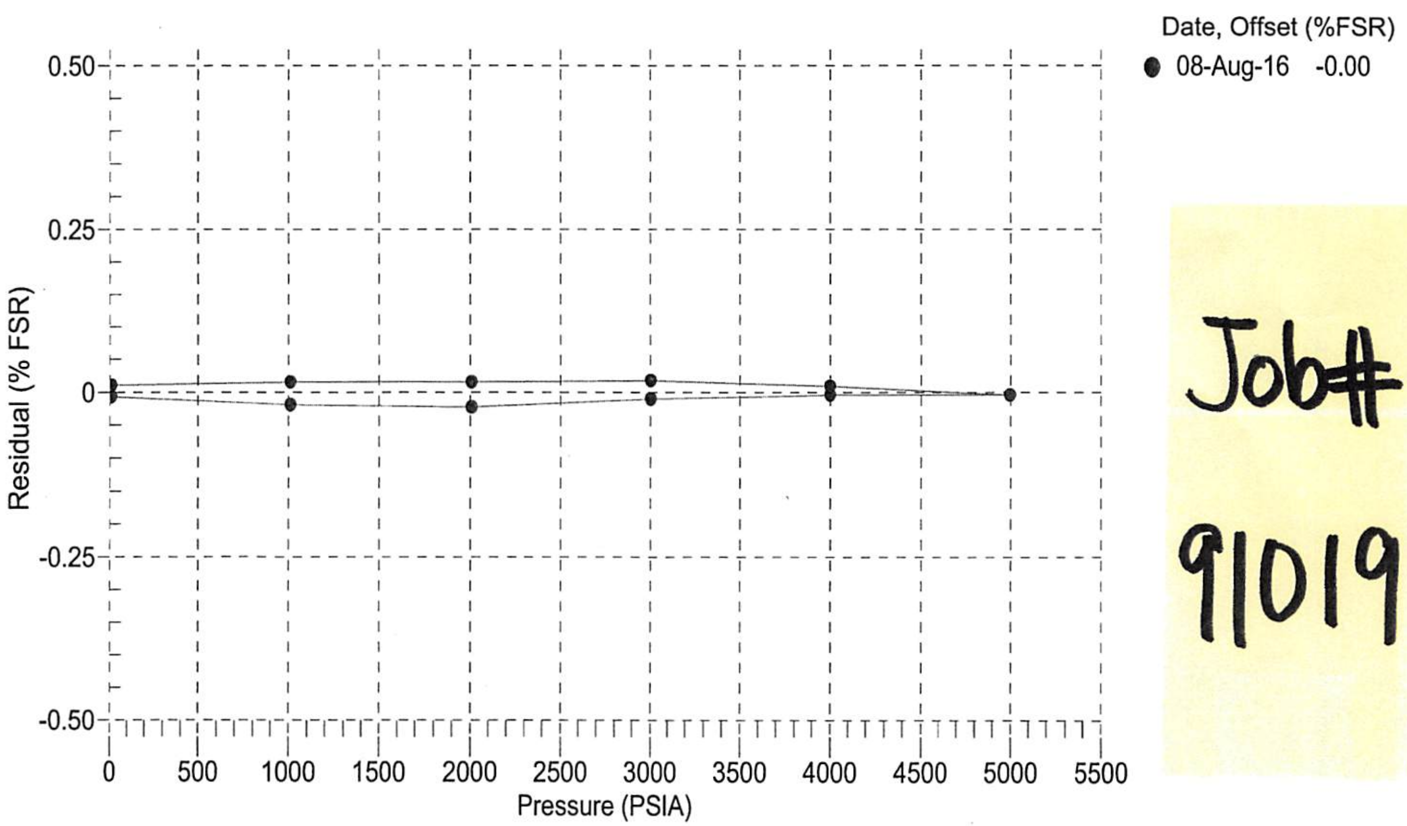
| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) | LINEAR FIT (PSIA) | LINEAR RESIDUAL (%FSR) |
|---|---|---|---|---|---|
| 14.59 | 3835.9 | 14.28 | -0.01 | 14.06 | -0.01 |
| 1011.42 | 2302.5 | 1010.44 | -0.02 | 1010.50 | -0.02 |
| 2008.31 | 768.5 | 2007.14 | -0.02 | 2007.32 | -0.02 |
| 3005.36 | -766.8 | 3004.83 | -0.01 | 3004.99 | -0.01 |
| 4002.24 | -2301.1 | 4002.02 | -0.00 | 4002.01 | -0.00 |
| 4999.20 | -3834.8 | 4998.97 | -0.00 | 4998.64 | -0.01 |
| 4002.27 | -2302.2 | 4002.74 | 0.01 | 4002.72 | 0.01 |
| 3005.47 | -769.2 | 3006.39 | 0.02 | 3006.55 | 0.02 |
| 2008.33 | 765.5 | 2009.09 | 0.02 | 2009.27 | 0.02 |
| 1011.30 | 2300.0 | 1012.06 | 0.02 | 1012.12 | 0.02 |
| 14.60 | 3834.6 | 15.12 | 0.01 | 14.91 | 0.01 |

n = instrument output (counts)

Straight Line Fit: Pressure (PSIA) = M * n + B

Quadratic Fit: Pressure (PSIA) = PA0 + PA1 * n + PA2 * $n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range




Job#
91019

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0810
CALIBRATION DATE: 11-Aug-16

SBE 19 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -4.11206262e+000
h = 4.90916191e-001
i = 1.09409039e-003
j = -2.89900237e-005

CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

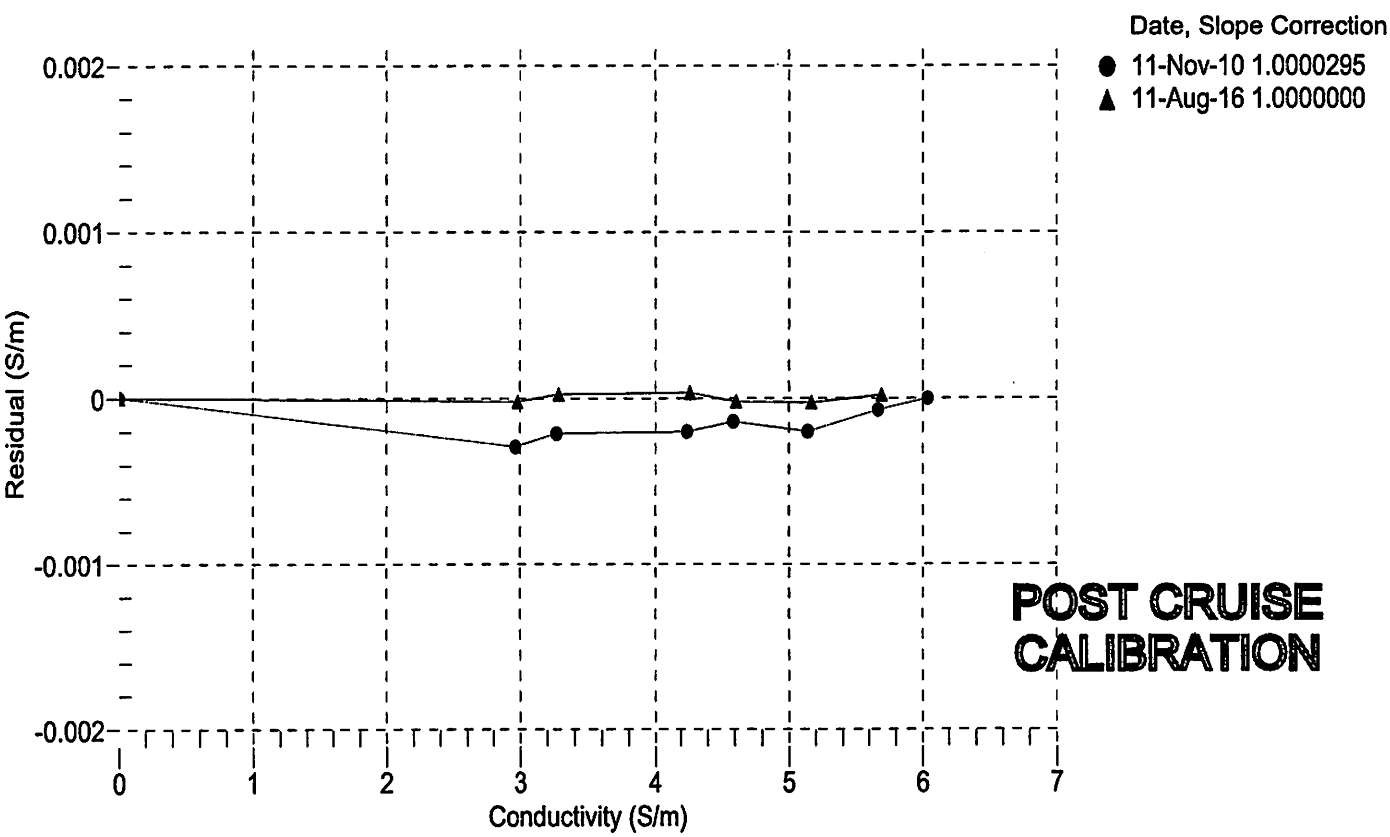
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (kHz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2.88563 | 0.00000 | 0.00000 |
| 1.0000 | 34.8206 | 2.97630 | 8.24780 | 2.97628 | -0.00002 |
| 4.5000 | 34.8011 | 3.28343 | 8.61178 | 3.28345 | 0.00002 |
| 15.0000 | 34.7590 | 4.26533 | 9.68308 | 4.26536 | 0.00003 |
| 18.5000 | 34.7500 | 4.61052 | 10.03225 | 4.61050 | -0.00002 |
| 24.0001 | 34.7402 | 5.16857 | 10.57224 | 5.16854 | -0.00003 |
| 28.9999 | 34.7351 | 5.69050 | 11.05330 | 5.69052 | 0.00002 |
| 32.4999 | 34.7325 | 6.06302 | 11.38420 | 6.06316 | 0.00014 |

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



# Sea-Bird Electronics, Inc.

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SENSOR SERIAL NUMBER: 0810
CALIBRATION DATE: 11-Aug-16

SBE 19 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

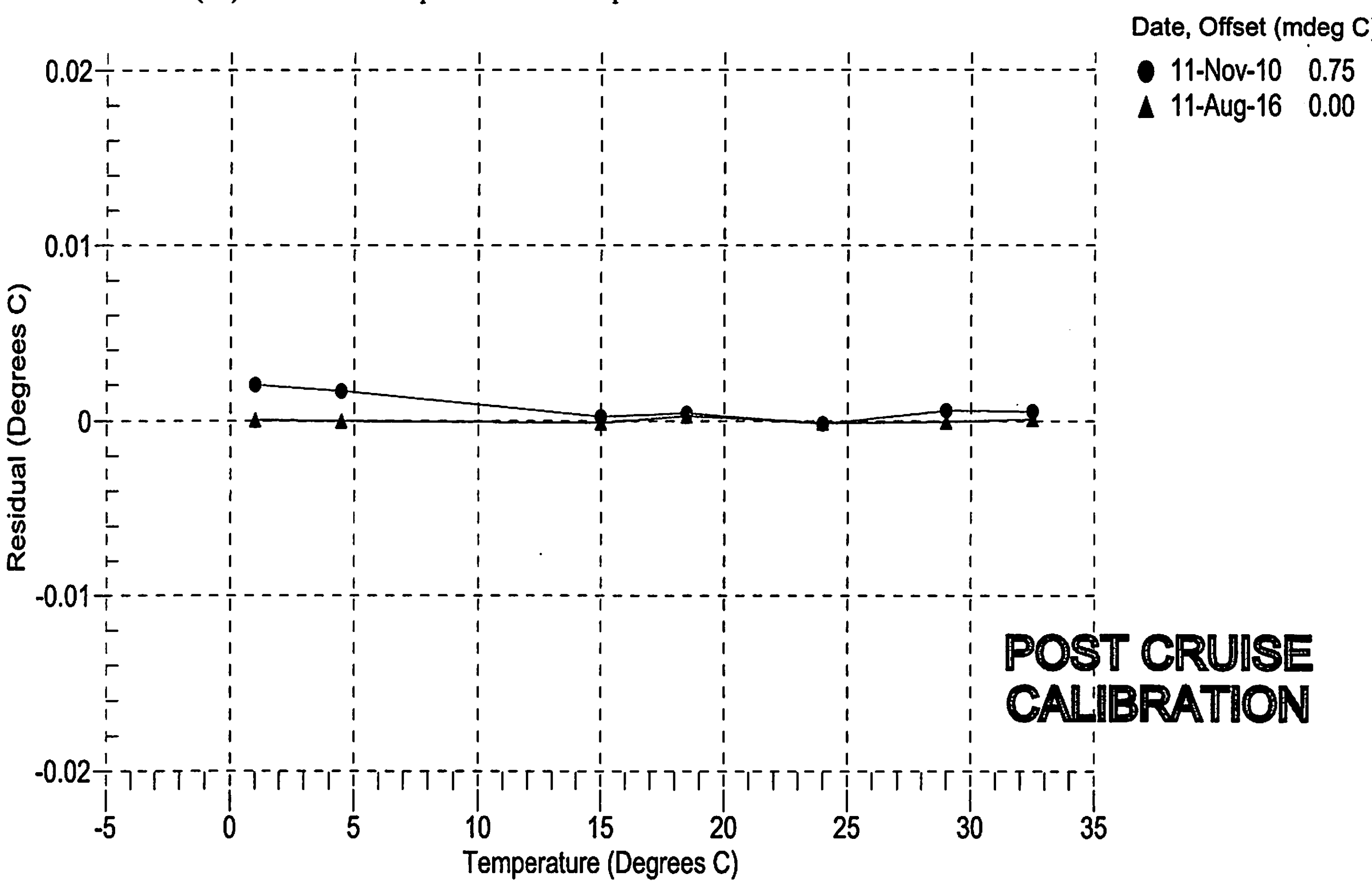
```
g =  4.21619640e-003
h =  6.07390270e-004
i =  7.30806845e-006
j = -1.24473843e-006
f0 =  1000.0
```

| BATH TEMP (° C) | INSTRUMENT OUTPUT (Hz) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 2582.209 | 1.0000 | 0.00002 |
| 4.5000 | 2791.754 | 4.5000 | -0.00002 |
| 15.0000 | 3492.690 | 14.9999 | -0.00015 |
| 18.5000 | 3751.628 | 18.5003 | 0.00027 |
| 24.0001 | 4185.263 | 24.0000 | -0.00012 |
| 28.9999 | 4608.880 | 28.9998 | -0.00006 |
| 32.4999 | 4922.630 | 32.5000 | 0.00006 |

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



SEA·BIRD SCIENTIFIC

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www.seabird.com

**SERVICE REPORT**

**Service Request** 91019R
**Date** 04-OCT-2016

## PRODUCT INFORMATION

**Item:** 19.LEGACY
**Item Description:** (LEGACY) SBE 19 CTD
**Serial:** 1947104-0810

**Special Notes**
Services Requested:
Evaluate/Repair Instrumentation.
Perform Routine Calibration Service.

Problems Found:
No problems found

Services Performed:
Perform initial diagnostic evaluation.
Performed "POST" cruise calibration.
Performed pressure calibration.
Performed complete system check and full diagnostic evaluation.

| Item | Item Description | Qty |
|---|---|---|
| 17028 | CABLE, 8', PIGTAIL TO RMG-2FS / DWG 30579 | 4 |
| 172251 | Y-CABLE, DUAL ECO-FL (DIFF) / 33183 | 4 |
| 23168 | PROFILER CONNECTOR END LIFT EYE /20217.2A | 3 |
| SERVICE19 | CONFIRM / RECERTIFY SBE 19/19PLUS/19PLUSV2. COMPLETE EXTERNAL INSPECTION. TEST ALL FUNCTIONS AND INPUT CHANNEL RESPONSES (FRRF) | 1 |

**Unbilled Items**

| Item | Item Description | Qty |
|---|---|---|
| | | |

SonTek
a xylem brand

**9940 Summers Ridge Road**
**San Diego, CA 92121**
**Tel: (858) 546-8327**
**support@sontek.com**

# CALIBRATION CERTIFICATE

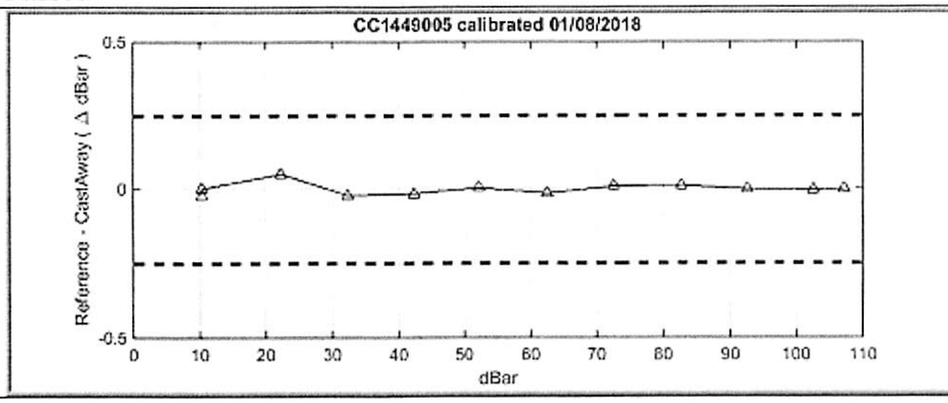
**SYSTEM INFO**

| | |
|---|---|
| System Type | CastAway-CTD |
| Serial Number | CC1449005 |
| Firmware Version | 1.60 |
| Date | 01/10/2018 |

**POWER CONSUMPTION**

| | |
|---|---|
| Standby Mode (A) | 0.2101 / PASS |
| Supply Voltage | 2.9V |

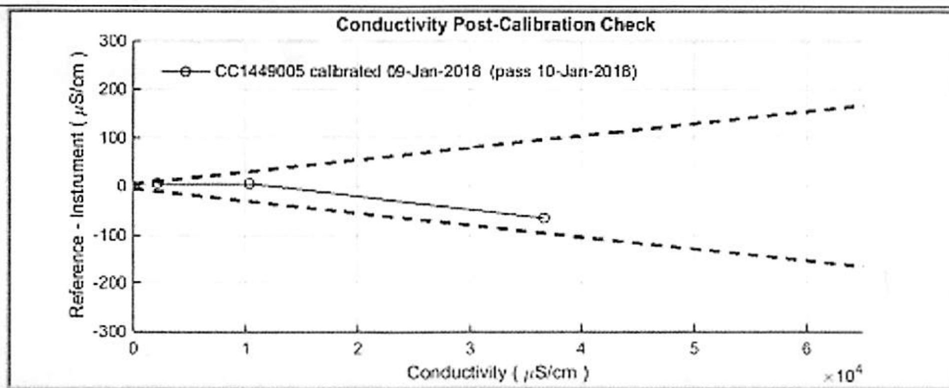
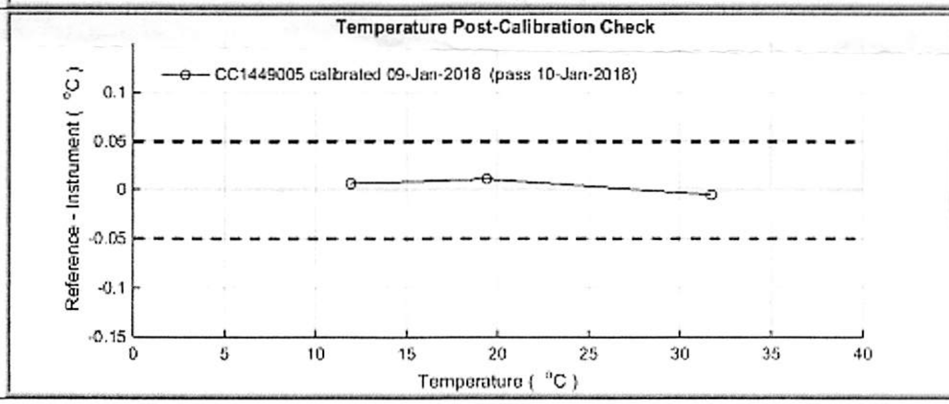
**CALIBRATION**

| | |
|---|---|
| GPS | Passed |
| Pressure |  |

SonTek

a xylem brand

9949 Summers Ridge Road • San Diego, CA 92121 • Telephone (858) 546-8327 • Fax (858) 546-8150 • Internet: www.sontek.com

| | |
|---|---|
| Conductivity |   |
| Temperature |   |

Verified by: Thanh.Nguyen

This report was generated on: 01/11/18

ATTENTION: New Warranty Terms as of March 4, 2013:

This system is covered under a two year limited warranty that extends to all parts and labor for any malfunction due to workmanship or errors in the manufacturing process. The warranty is valid only if you properly maintain and operate this system under normal use as outlined in the User's Manual. The warranty does not cover shortcomings that are due to the design, or any incidental damages as a result of errors in the measurements.

SonTek will repair and/or replace, at its sole option, any product established to be defective with a product of like type. CLAIMS FOR LABOR COSTS AND/OR OTHER CHARGES RESULTING FROM THE USE OF SonTek GOODS AND/OR PRODUCTS ARE NOT COVERED BY THIS LIMITED WARRANTY.

SonTek DISCLAIMS ALL EXPRESS WARRANTIES OTHER THAN THOSE CONTAINED ABOVE AND ALL IMPLIED WARRANTIES, INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR A PARTICULAR PURPOSE. SonTek DISCLAIMS AND WILL NOT BE LIABLE, UNDER ANY CIRCUMSTANCE, IN CONTRACT, TORT OR WARRANTY, FOR ANY SPECIAL, INDIRECT, INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING BUT NOT LIMITED TO LOST PROFITS, BUSINESS INTERRUPTION LOSSES, LOSS OF GOODWILL, OR LOSS OF BUSINESS OR CUSTOMER RELATIONSHIPS.

If your system is not functioning properly, first try to identify the source of the problem. If additional support is required, we encourage you to contact us immediately. We will work to resolve the problem as quickly as possible.

If the system needs to be returned to the factory, please contact SonTek to obtain a Service Request (SR) number. We reserve the right to refuse receipt of shipments without SRs. We require the system to be shipped back in the original shipping container using the original packing material with all delivery costs covered by the customer (including all taxes and duties). If the system is returned without appropriate packing, the customer will be required to cover the cost of a new packaging crate and material.

The warranty for repairs performed at an authorized SonTek Service Center is one year.

Sea-Bird Scientific
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www.seabird.com

SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 12-Dec-17

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:
g = -9.977869e-001
h = 1.374792e-001
i = -3.135771e-004
j = 4.190110e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

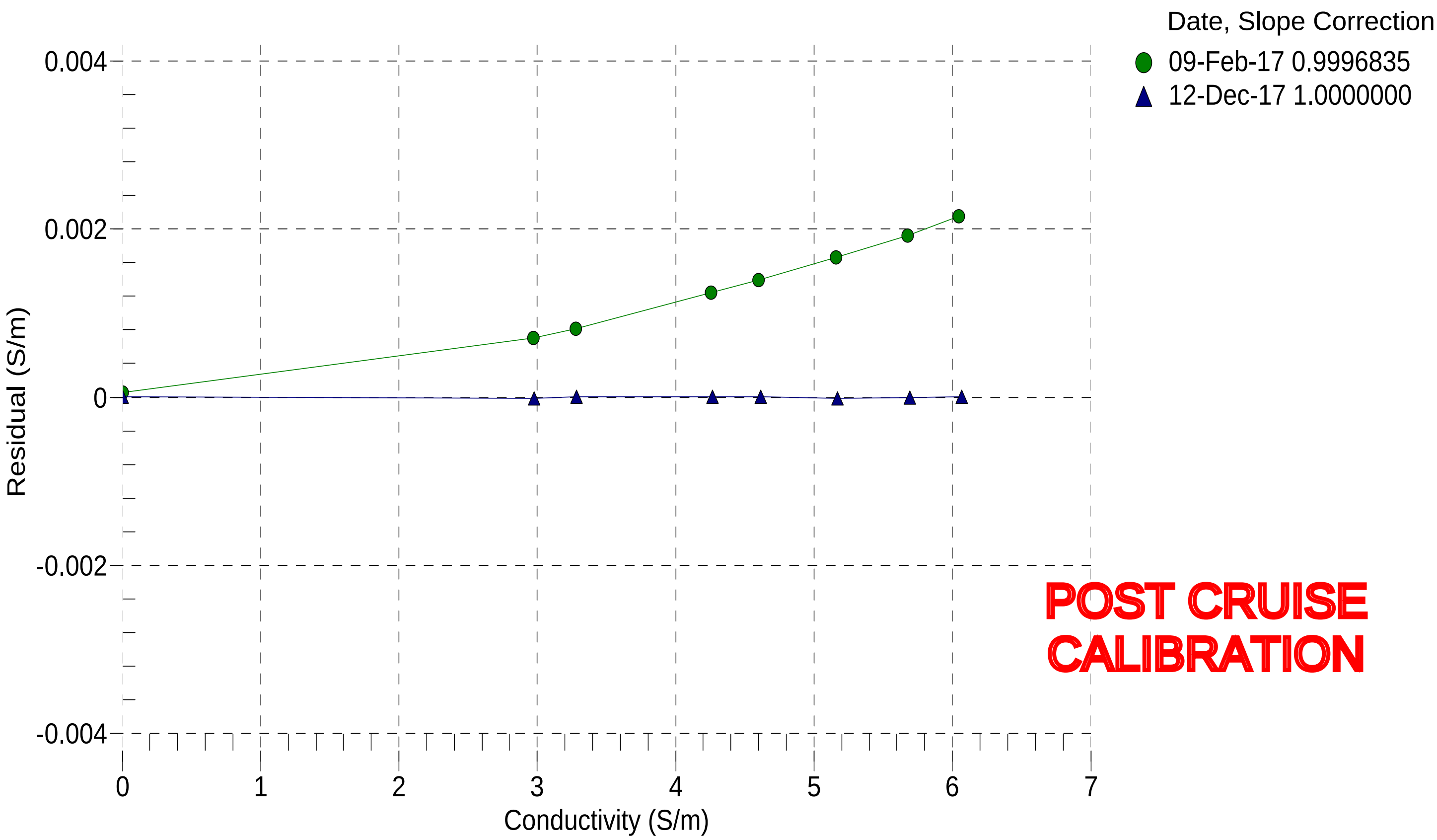
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2699.34 | 0.0000 | 0.00000 |
| 1.0000 | 34.8427 | 2.97801 | 5386.94 | 2.9780 | -0.00001 |
| 4.5000 | 34.8232 | 3.28531 | 5590.68 | 3.2853 | 0.00001 |
| 15.0001 | 34.7813 | 4.26778 | 6196.43 | 4.2678 | 0.00001 |
| 18.5000 | 34.7725 | 4.61319 | 6395.47 | 4.6132 | 0.00000 |
| 24.0000 | 34.7631 | 5.17159 | 6704.43 | 5.1716 | -0.00001 |
| 28.9999 | 34.7581 | 5.69385 | 6980.67 | 5.6938 | -0.00001 |
| 32.4999 | 34.7554 | 6.06656 | 7171.10 | 6.0666 | 0.00001 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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USA

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seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 16-Dec-17

SBE 19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.021594e+000
h = 1.396230e-001
i = -2.363477e-004
j = 3.809685e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

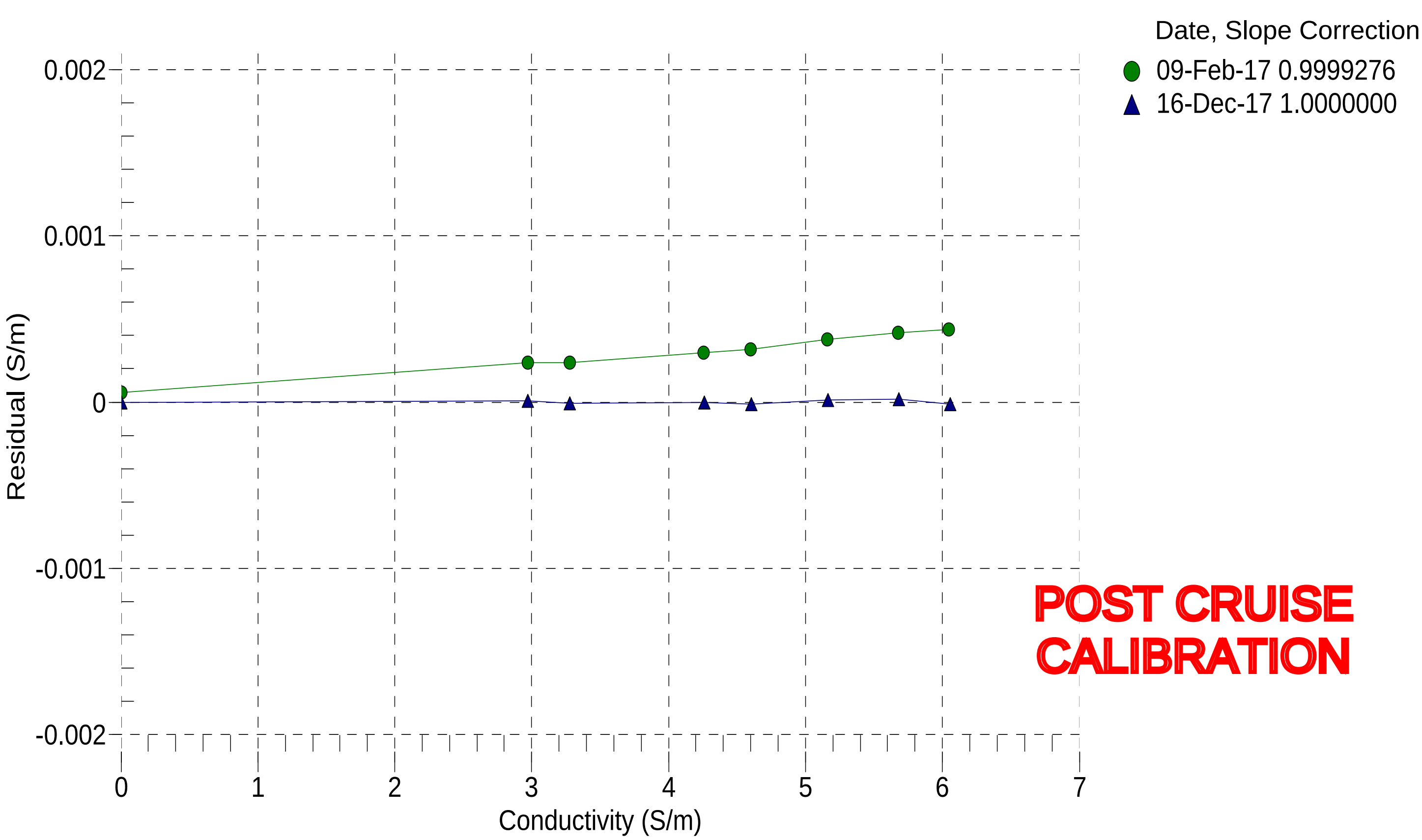
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2708.46 | 0.0000 | 0.00000 |
| 1.0000 | 34.7704 | 2.97242 | 5351.77 | 2.9724 | 0.00001 |
| 4.5000 | 34.7507 | 3.27914 | 5552.77 | 3.2791 | -0.00001 |
| 15.0000 | 34.7088 | 4.25982 | 6150.70 | 4.2598 | -0.00000 |
| 18.5000 | 34.7000 | 4.60460 | 6347.24 | 4.6046 | -0.00001 |
| 24.0000 | 34.6900 | 5.16191 | 6652.37 | 5.1619 | 0.00001 |
| 29.0000 | 34.6839 | 5.68307 | 6925.20 | 5.6831 | 0.00002 |
| 32.5001 | 34.6797 | 6.05487 | 7113.22 | 6.0549 | -0.00001 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 04-Dec-17

SBE 19plus PRESSURE CALIBRATION DATA
1450 psia S/N 2101

COEFFICIENTS:

```
PA0 =       5.940783e-001
PA1 =       4.437308e-003
PA2 =      -2.171621e-011
PTEMPA0 = -8.026650e+001
PTEMPA1 =  4.669965e+001
PTEMPA2 = -2.433074e-001

PTCA0 =  5.211001e+005
PTCA1 =  8.822587e+000
PTCA2 = -1.211043e-001
PTCB0 =  2.480825e+001
PTCB1 = -3.500000e-004
PTCB2 =  0.000000e+000
```

## PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.89 | 524452.3 | 2.2 | 14.88 | -0.00 |
| 300.81 | 588884.5 | 2.2 | 300.78 | -0.00 |
| 588.22 | 653692.8 | 2.2 | 588.15 | -0.00 |
| 875.55 | 718548.8 | 2.2 | 875.56 | 0.00 |
| 1162.92 | 783432.2 | 2.2 | 1162.91 | -0.00 |
| 1450.14 | 848335.9 | 2.2 | 1450.16 | 0.00 |
| 1163.11 | 783472.0 | 2.2 | 1163.08 | -0.00 |
| 875.88 | 718616.7 | 2.2 | 875.86 | -0.00 |
| 588.20 | 653729.9 | 2.2 | 588.32 | 0.01 |
| 300.91 | 588920.3 | 2.2 | 300.93 | 0.00 |
| 14.89 | 524456.2 | 2.2 | 14.90 | 0.00 |

## THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 2.45 | 524532.46 |
| 29.00 | 2.37 | 524549.52 |
| 24.00 | 2.26 | 524530.45 |
| 18.50 | 2.14 | 524502.60 |
| 15.00 | 2.06 | 524484.11 |
| 4.50 | 1.83 | 524418.43 |
| 1.00 | 1.76 | 524395.89 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 24.81 |
| 35.00 | 24.80 |

y = thermistor output (counts)

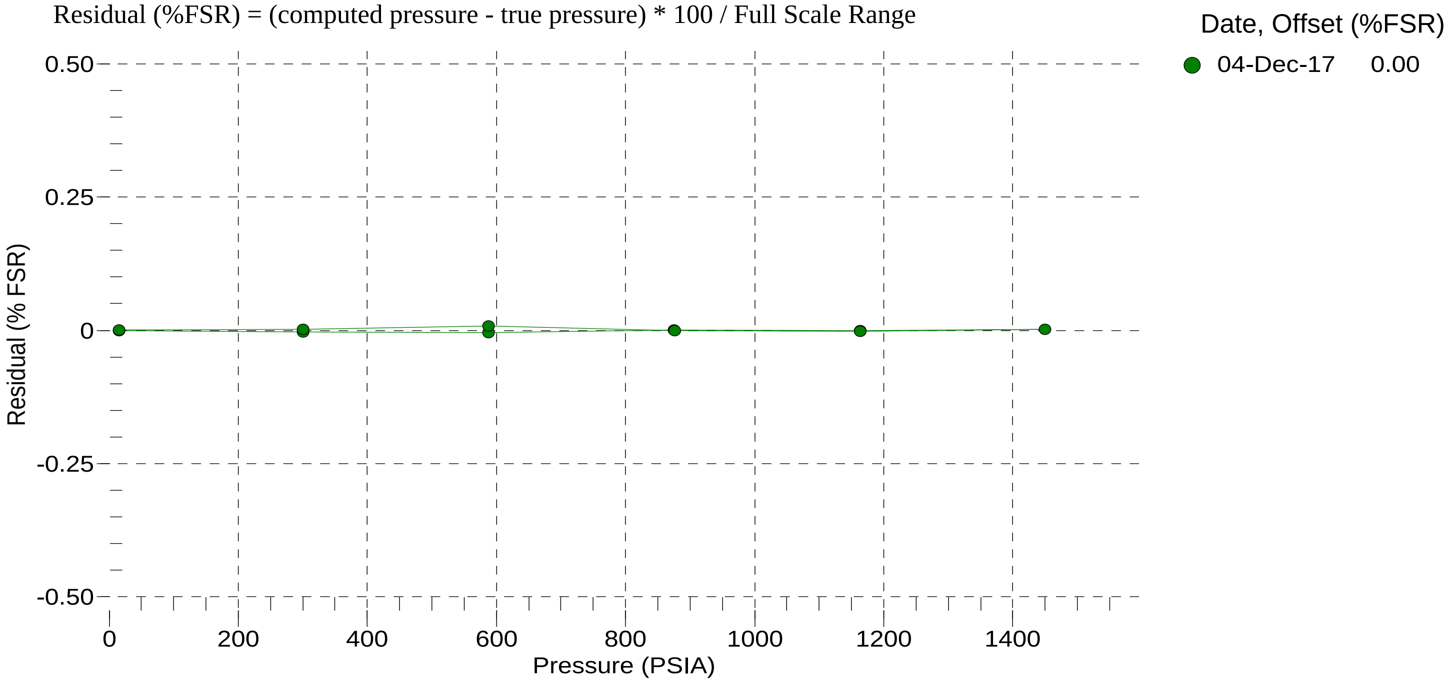
$t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{instrument output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (PSIA)} = PA0 + PA1 * n + PA2 * n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 11-Dec-17

SBE 19plus PRESSURE CALIBRATION DATA
508 psia S/N 2837

COEFFICIENTS:

PA0 = 7.396059e-002
PA1 = 1.556819e-003
PA2 = 6.769618e-012
PTEMPA0 = -7.395494e+001
PTEMPA1 = 4.848425e+001
PTEMPA2 = -2.187811e-001

PTCA0 = 5.242489e+005
PTCA1 = 4.544278e+000
PTCA2 = -1.085417e-001
PTCB0 = 2.498675e+001
PTCB1 = -5.000000e-005
PTCB2 = 0.000000e+000

PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.77 | 533741.0 | 2.0 | 14.78 | 0.00 |
| 105.03 | 591688.0 | 2.0 | 105.03 | -0.00 |
| 205.04 | 655855.0 | 2.0 | 205.01 | -0.01 |
| 305.04 | 720001.0 | 2.0 | 305.02 | -0.00 |
| 405.04 | 784107.0 | 2.0 | 405.03 | -0.00 |
| 505.05 | 848182.0 | 2.0 | 505.04 | -0.00 |
| 405.04 | 784134.0 | 2.0 | 405.07 | 0.01 |
| 305.04 | 720029.0 | 2.0 | 305.07 | 0.00 |
| 205.04 | 655883.0 | 2.0 | 205.06 | 0.00 |
| 105.04 | 591704.0 | 2.0 | 105.05 | 0.00 |
| 14.77 | 533733.0 | 2.0 | 14.77 | -0.00 |

THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 2.22 | 533869.31 |
| 29.00 | 2.14 | 533880.39 |
| 24.00 | 2.04 | 533884.65 |
| 18.50 | 1.92 | 533884.17 |
| 15.00 | 1.85 | 533880.95 |
| 4.50 | 1.63 | 533856.20 |
| 1.00 | 1.56 | 533842.36 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 24.99 |
| 35.00 | 24.98 |

y = thermistor output (counts)

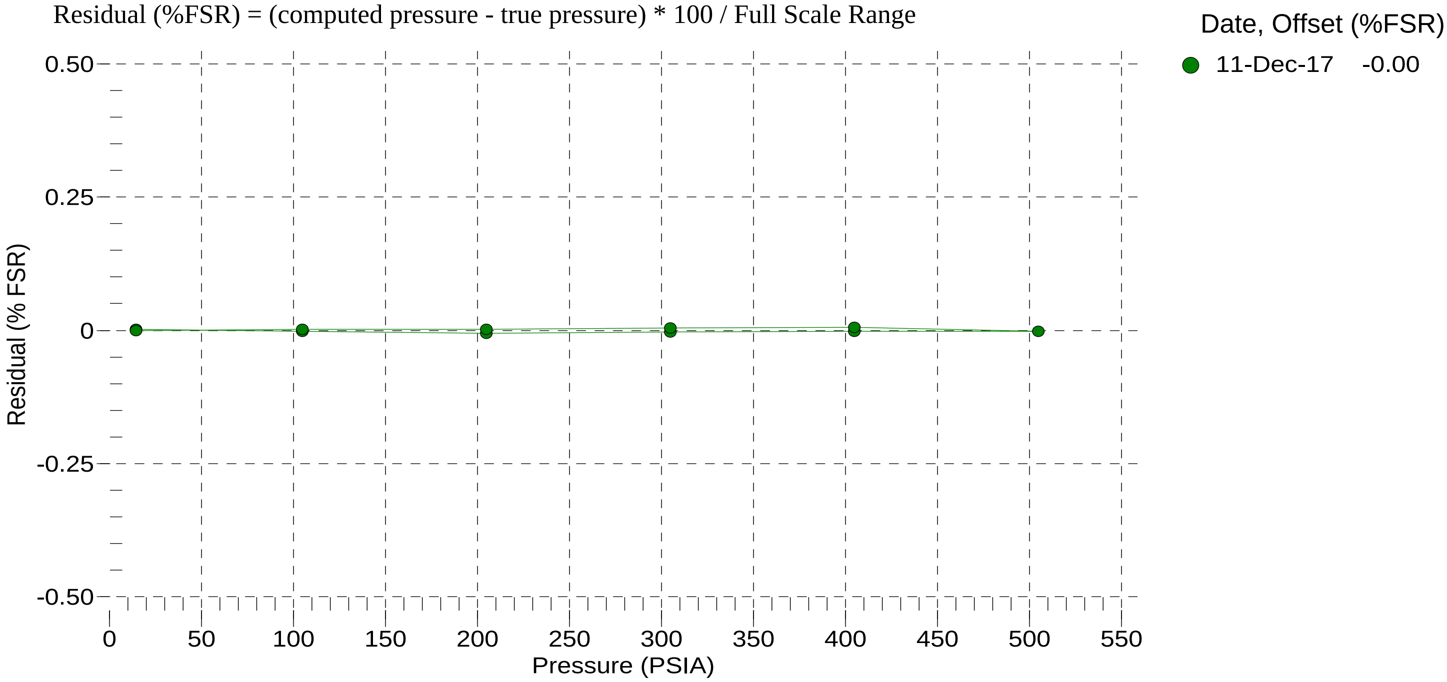
$t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

$x = \text{instrument output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$

$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$

$\text{pressure (PSIA)} = PA0 + PA1 * n + PA2 * n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 4343
CALIBRATION DATE: 12-Dec-17

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

```
a0 =  1.200607e-003
a1 =  2.637963e-004
a2 = -2.405851e-008
a3 =  1.485148e-007
```

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 693463.034 | 1.0000 | 0.0000 |
| 4.5000 | 619957.695 | 4.5000 | -0.0000 |
| 15.0001 | 434183.271 | 15.0002 | 0.0001 |
| 18.5000 | 383459.932 | 18.4999 | -0.0001 |
| 24.0000 | 313986.288 | 24.0000 | 0.0000 |
| 28.9999 | 260622.847 | 28.9999 | 0.0000 |
| 32.4999 | 228181.254 | 32.4999 | -0.0000 |

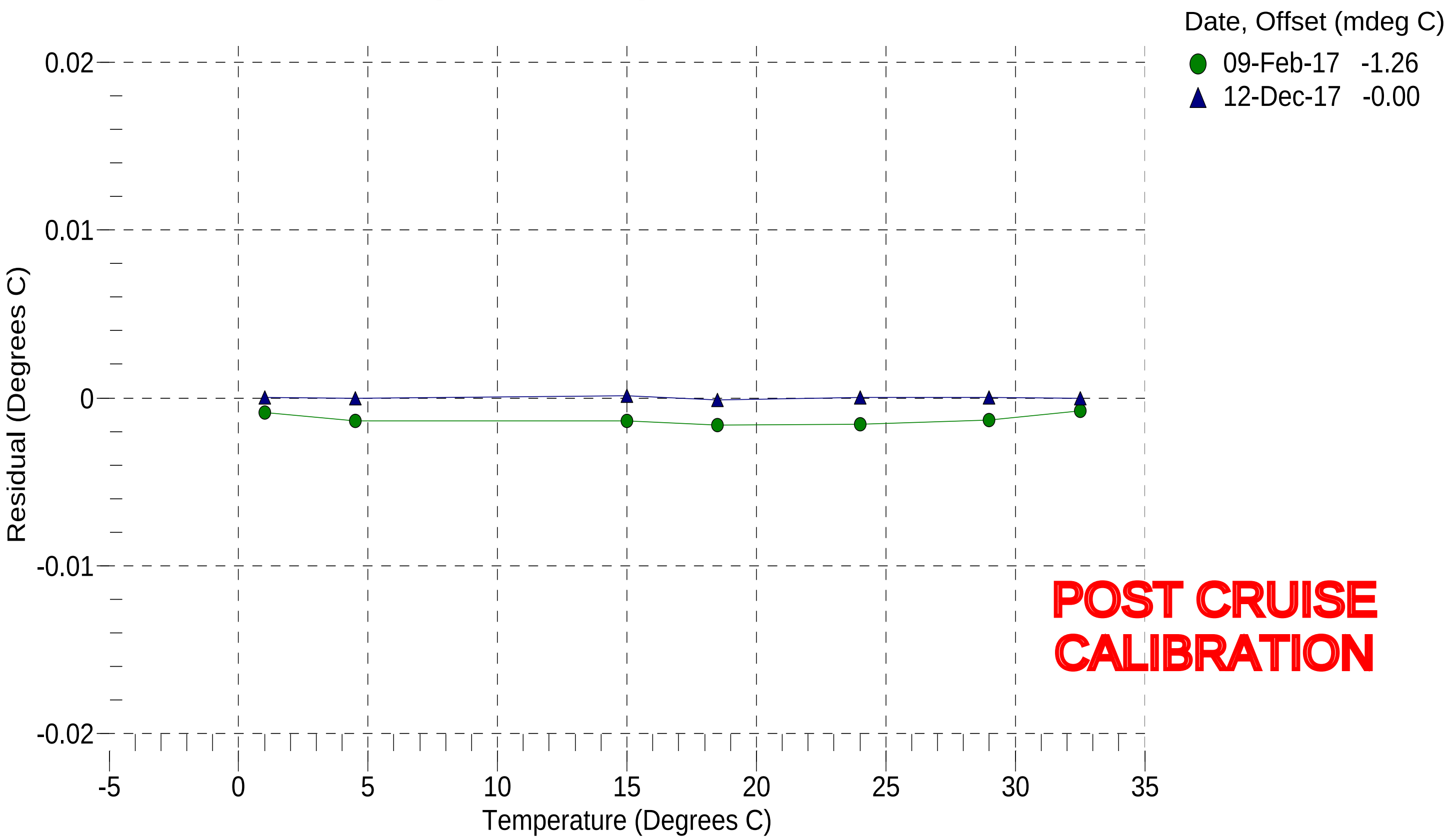
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(R)] + a2[ln^2(R)] + a3[ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 4487
CALIBRATION DATE: 16-Dec-17

SBE 19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.229836e-003
a1 = 2.552982e-004
a2 = 6.992801e-007
a3 = 1.160010e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 713465.153 | 1.0001 | 0.0001 |
| 4.5000 | 638146.525 | 4.4998 | -0.0002 |
| 15.0000 | 447155.644 | 15.0003 | 0.0003 |
| 18.5000 | 394891.390 | 18.5000 | -0.0000 |
| 24.0000 | 323257.898 | 23.9999 | -0.0001 |
| 29.0000 | 268210.644 | 28.9999 | -0.0001 |
| 32.5001 | 234743.153 | 32.5002 | 0.0001 |

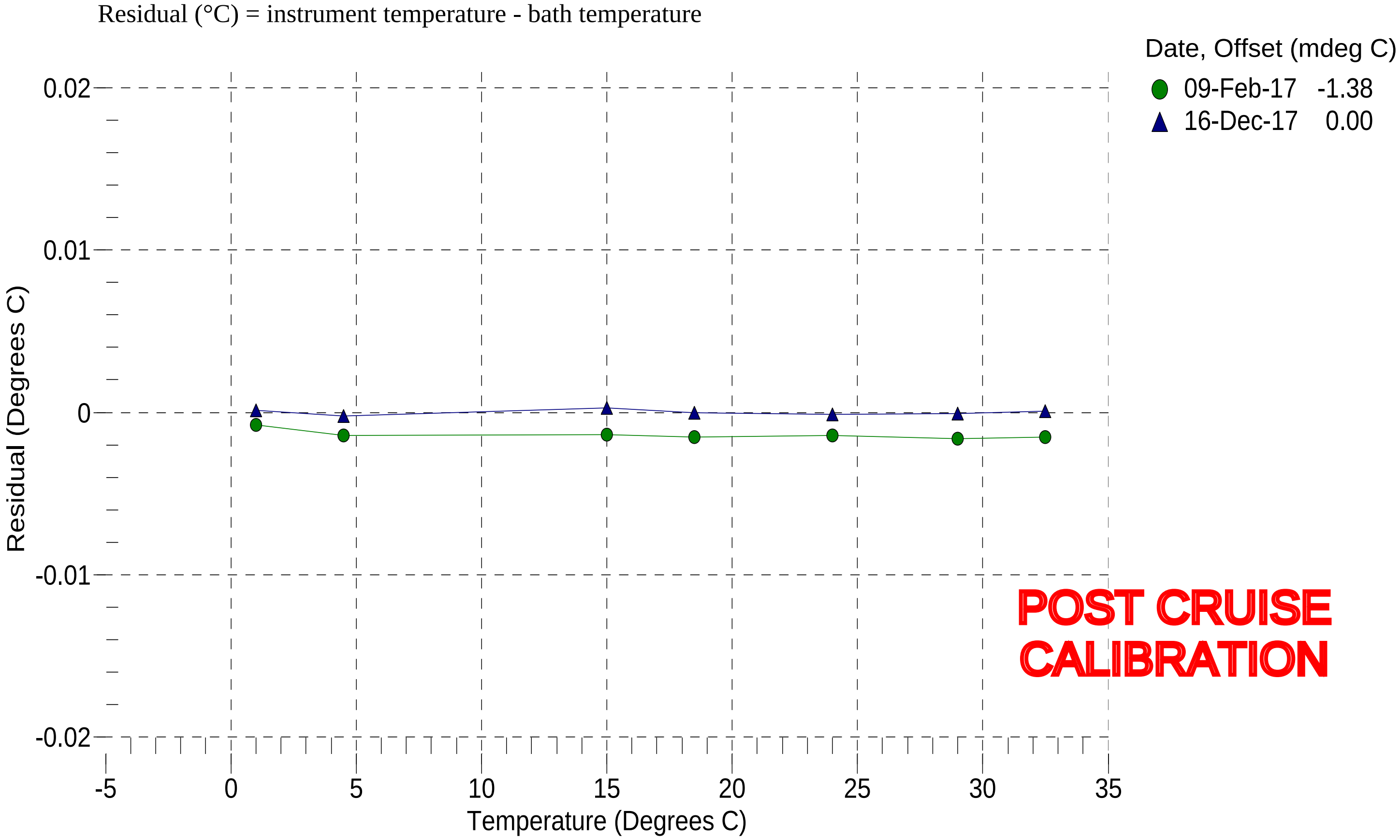
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[\ln(R)] + a2[\ln^2(R)] + a3[\ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 07-Dec-17

SBE 19plus V2 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -1.020276e+000
h =   1.332896e-001
i =   2.482739e-004
j =   1.160830e-006

CPcor = -9.5700e-008
CTcor =  3.2500e-006
```

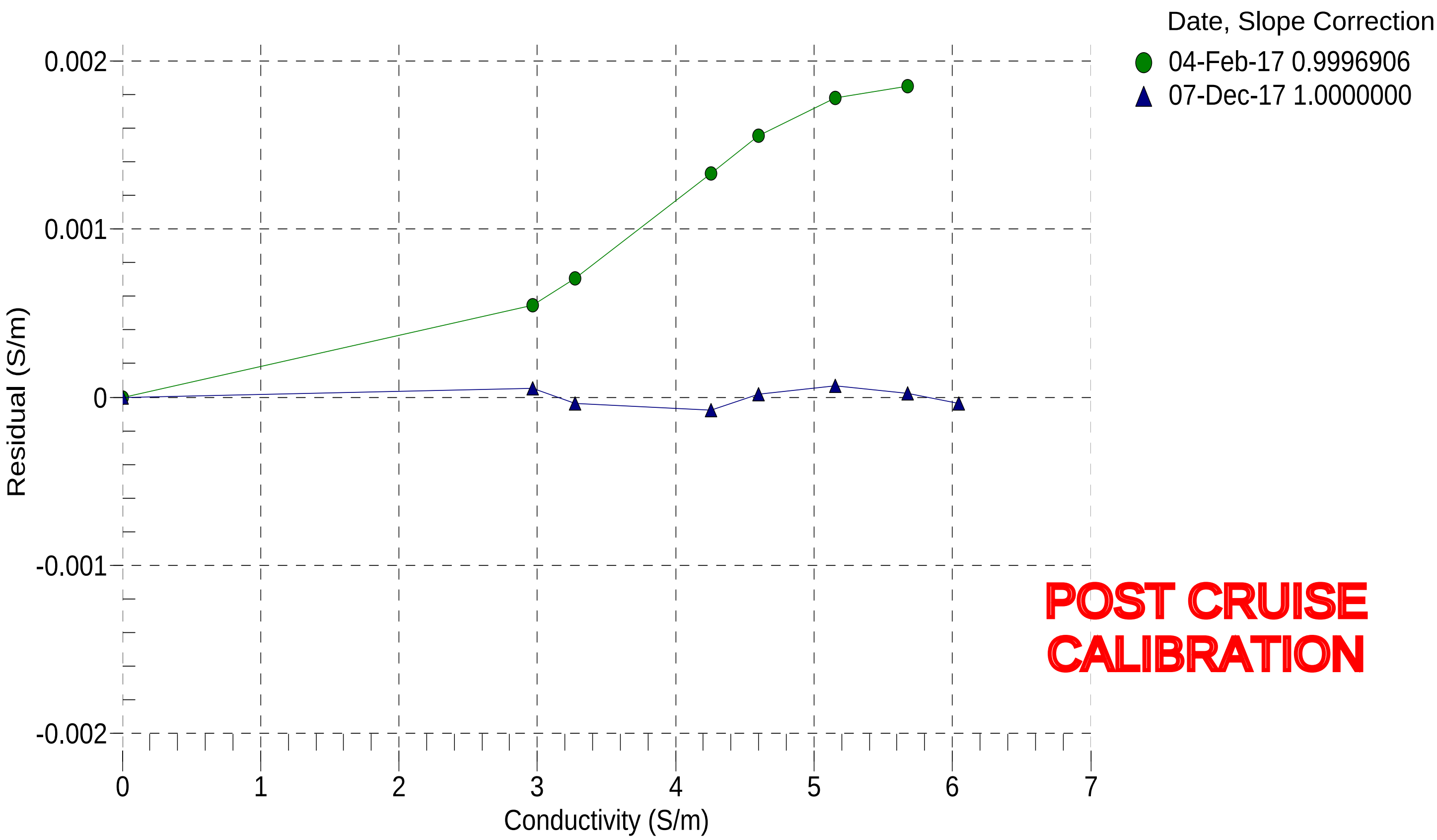
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2759.51 | 0.0000 | 0.00000 |
| 1.0000 | 34.7126 | 2.96794 | 5441.89 | 2.9680 | 0.00005 |
| 4.4999 | 34.6929 | 3.27422 | 5645.82 | 3.2742 | -0.00004 |
| 15.0000 | 34.6511 | 4.25349 | 6252.88 | 4.2534 | -0.00008 |
| 18.4999 | 34.6423 | 4.59776 | 6452.58 | 4.5978 | 0.00002 |
| 24.0000 | 34.6324 | 5.15429 | 6762.66 | 5.1544 | 0.00007 |
| 29.0000 | 34.6264 | 5.67471 | 7040.01 | 5.6747 | 0.00002 |
| 32.5000 | 34.6221 | 6.04594 | 7231.21 | 6.0459 | -0.00004 |

f = Instrument Output (Hz) / 1000.0

t = temperature (°C);  p = pressure (decibars);  $\delta$ = CTcor;  $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 5-Dec-17

SBE 19plus V2 PRESSURE CALIBRATION DATA
870 psia S/N 3182130

COEFFICIENTS:

| | |
|---|---|
| PA0 = 1.967040e+000 | PTCA0 = 5.245776e+005 |
| PA1 = 2.627831e-003 | PTCA1 = 5.244279e+001 |
| PA2 = 2.201140e-011 | PTCA2 = -8.412054e-001 |
| PTEMPA0 = -6.484784e+001 | PTCB0 = 2.523813e+001 |
| PTEMPA1 = 5.086978e+001 | PTCB1 = -9.750000e-004 |
| PTEMPA2 = 1.053404e-002 | PTCB2 = 0.000000e+000 |

PRESSURE SPAN CALIBRATION

| PRESSURE (PSIA) | INSTRUMENT OUTPUT (counts) | THERMISTOR OUTPUT (volts) | COMPUTED PRESSURE (PSIA) | RESIDUAL (%FSR) |
|---|---|---|---|---|
| 14.91 | 530236.0 | 1.7 | 14.88 | -0.00 |
| 180.17 | 593017.0 | 1.7 | 180.10 | -0.01 |
| 360.17 | 661346.0 | 1.7 | 360.12 | -0.01 |
| 540.17 | 729601.0 | 1.7 | 540.15 | -0.00 |
| 720.17 | 797774.0 | 1.7 | 720.16 | -0.00 |
| 870.16 | 854514.0 | 1.7 | 870.15 | -0.00 |
| 720.19 | 797793.0 | 1.7 | 720.21 | 0.00 |
| 540.21 | 729639.0 | 1.7 | 540.25 | 0.00 |
| 360.20 | 661391.0 | 1.7 | 360.24 | 0.00 |
| 180.19 | 593067.0 | 1.7 | 180.23 | 0.00 |
| 14.90 | 530260.0 | 1.7 | 14.94 | 0.00 |

THERMAL CORRECTION

| TEMP (°C) | THERMISTOR OUTPUT (volts) | INSTRUMENT OUTPUT (counts) |
|---|---|---|
| 32.50 | 1.91 | 530443.20 |
| 29.00 | 1.84 | 530427.40 |
| 24.00 | 1.75 | 530387.98 |
| 18.50 | 1.64 | 530305.39 |
| 15.00 | 1.57 | 530224.25 |
| 4.50 | 1.36 | 529837.37 |
| 1.00 | 1.29 | 529672.01 |

| TEMPERATURE (°C) | SPAN |
|---|---|
| -5.00 | 25.24 |
| 35.00 | 25.20 |

y = thermistor output (counts)

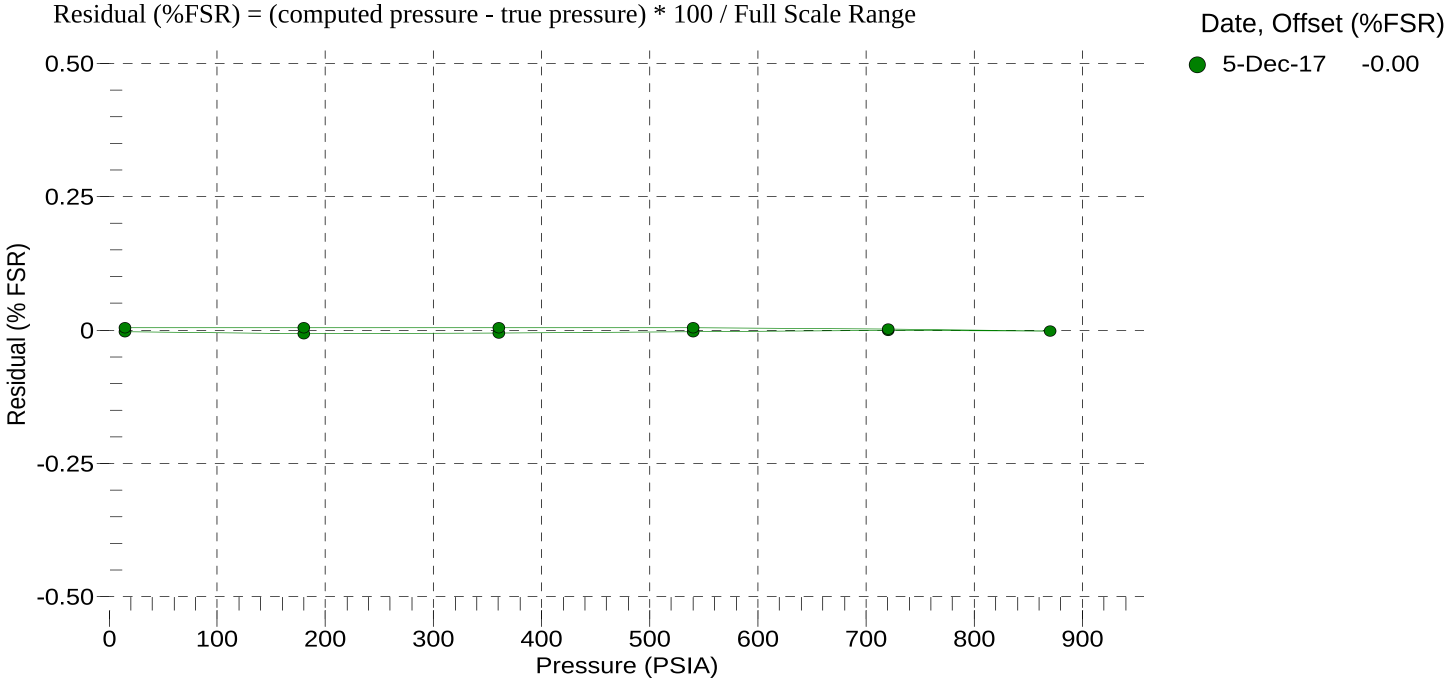
t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * $y^2$

x = instrument output - PTCA0 - PTCA1 * t - PTCA2 * $t^2$

n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * $t^2$)

pressure (PSIA) = PA0 + PA1 * n + PA2 * $n^2$

Residual (%FSR) = (computed pressure - true pressure) * 100 / Full Scale Range



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SENSOR SERIAL NUMBER: 6667
CALIBRATION DATE: 07-Dec-17

SBE 19plus V2 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:
a0 = 1.247850e-003
a1 = 2.590230e-004
a2 = -8.049346e-008
a3 = 1.406737e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 702146.102 | 1.0000 | 0.0000 |
| 4.4999 | 626320.780 | 4.4998 | -0.0001 |
| 15.0000 | 435060.661 | 15.0000 | 0.0000 |
| 18.4999 | 383026.458 | 18.4999 | 0.0000 |
| 24.0000 | 311975.356 | 24.0000 | -0.0000 |
| 29.0000 | 257616.051 | 28.9999 | -0.0001 |
| 32.5000 | 224682.169 | 32.5001 | 0.0001 |

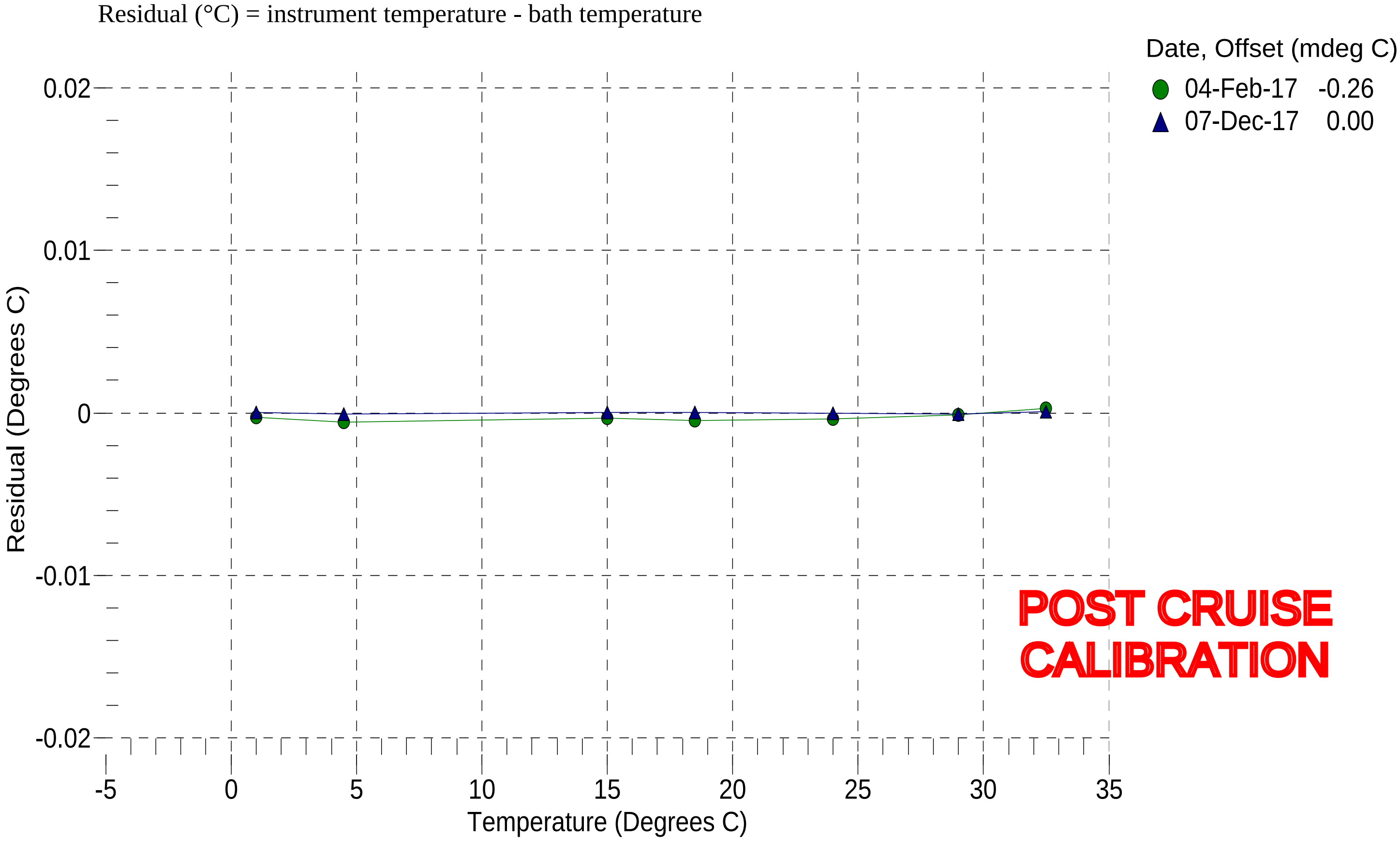
n = Instrument Output (counts)

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

Temperature ITS-90 (°C) = $1/\{a0 + a1[\ln(R)] + a2[\ln^2(R)] + a3[\ln^3(R)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 19-Dec-17

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.861110e-001
h =   1.720232e-001
i =  -4.163156e-004
j =   6.327184e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  2.4322e-007
```

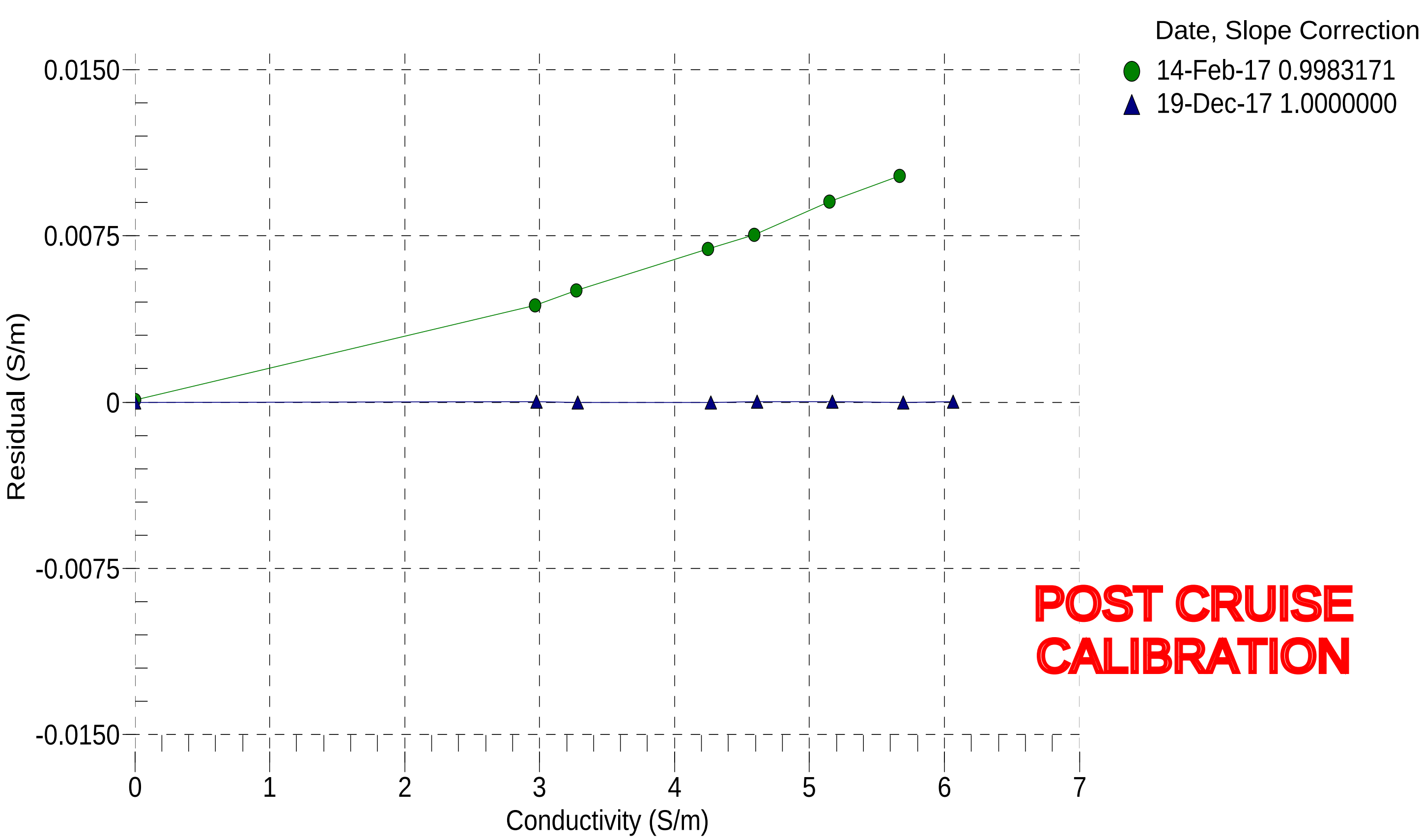
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2398.67 | 0.00000 | 0.00000 |
| 1.0000 | 34.8459 | 2.97825 | 4808.12 | 2.97826 | 0.00001 |
| 4.4999 | 34.8250 | 3.28545 | 4990.41 | 3.28545 | -0.00001 |
| 15.0000 | 34.7808 | 4.26772 | 5532.43 | 4.26772 | -0.00000 |
| 18.4999 | 34.7711 | 4.61301 | 5710.49 | 4.61301 | 0.00000 |
| 24.0000 | 34.7608 | 5.17128 | 5986.90 | 5.17129 | 0.00000 |
| 29.0000 | 34.7553 | 5.69345 | 6234.02 | 5.69344 | -0.00001 |
| 32.5000 | 34.7525 | 6.06612 | 6404.39 | 6.06613 | 0.00000 |

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); $\delta$ = CTcor; $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 09-Jan-18

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.835554e-001
h =  1.714970e-001
i = -3.521082e-004
j =  5.907637e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  2.4322e-007
```

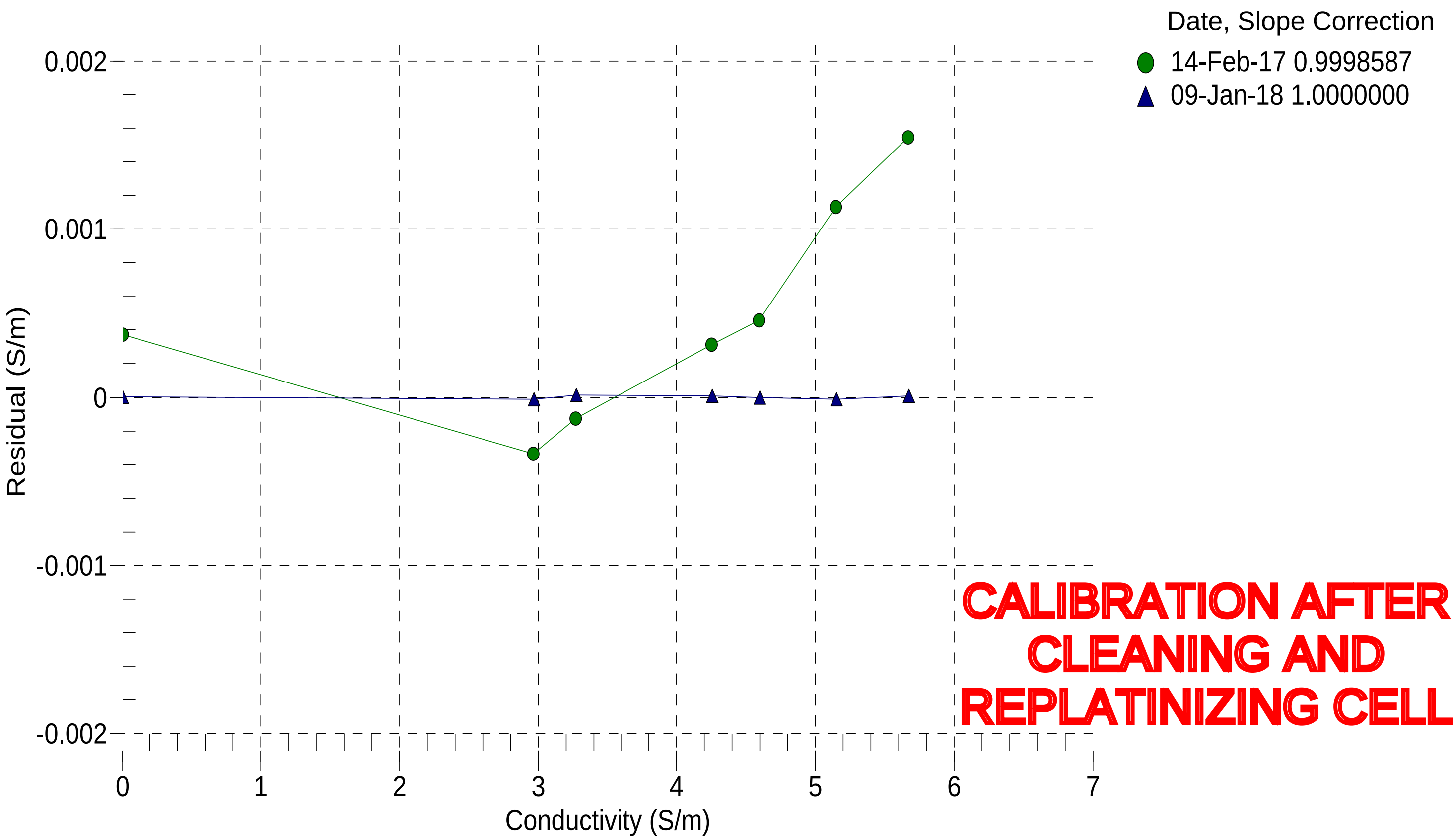
| BATH TEMP (° C) | BATH SAL (PSU) | BATH COND (S/m) | INSTRUMENT OUTPUT (Hz) | INSTRUMENT COND (S/m) | RESIDUAL (S/m) |
|---|---|---|---|---|---|
| 22.0000 | 0.0000 | 0.00000 | 2398.34 | 0.00000 | 0.00000 |
| 1.0000 | 34.7157 | 2.96818 | 4804.87 | 2.96817 | -0.00001 |
| 4.5000 | 34.6961 | 3.27450 | 4987.05 | 3.27451 | 0.00001 |
| 15.0000 | 34.6543 | 4.25384 | 5528.61 | 4.25384 | 0.00001 |
| 18.5000 | 34.6457 | 4.59817 | 5706.56 | 4.59817 | -0.00000 |
| 24.0000 | 34.6364 | 5.15482 | 5982.75 | 5.15480 | -0.00001 |
| 29.0000 | 34.6310 | 5.67537 | 6229.66 | 5.67538 | 0.00001 |
| 32.5000 | 34.6269 | 6.04669 | 6399.82 | 6.04679 | 0.00010 |

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C);   p = pressure (decibars);   $\delta$ = CTcor;   $\varepsilon$ = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 19-Dec-17

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

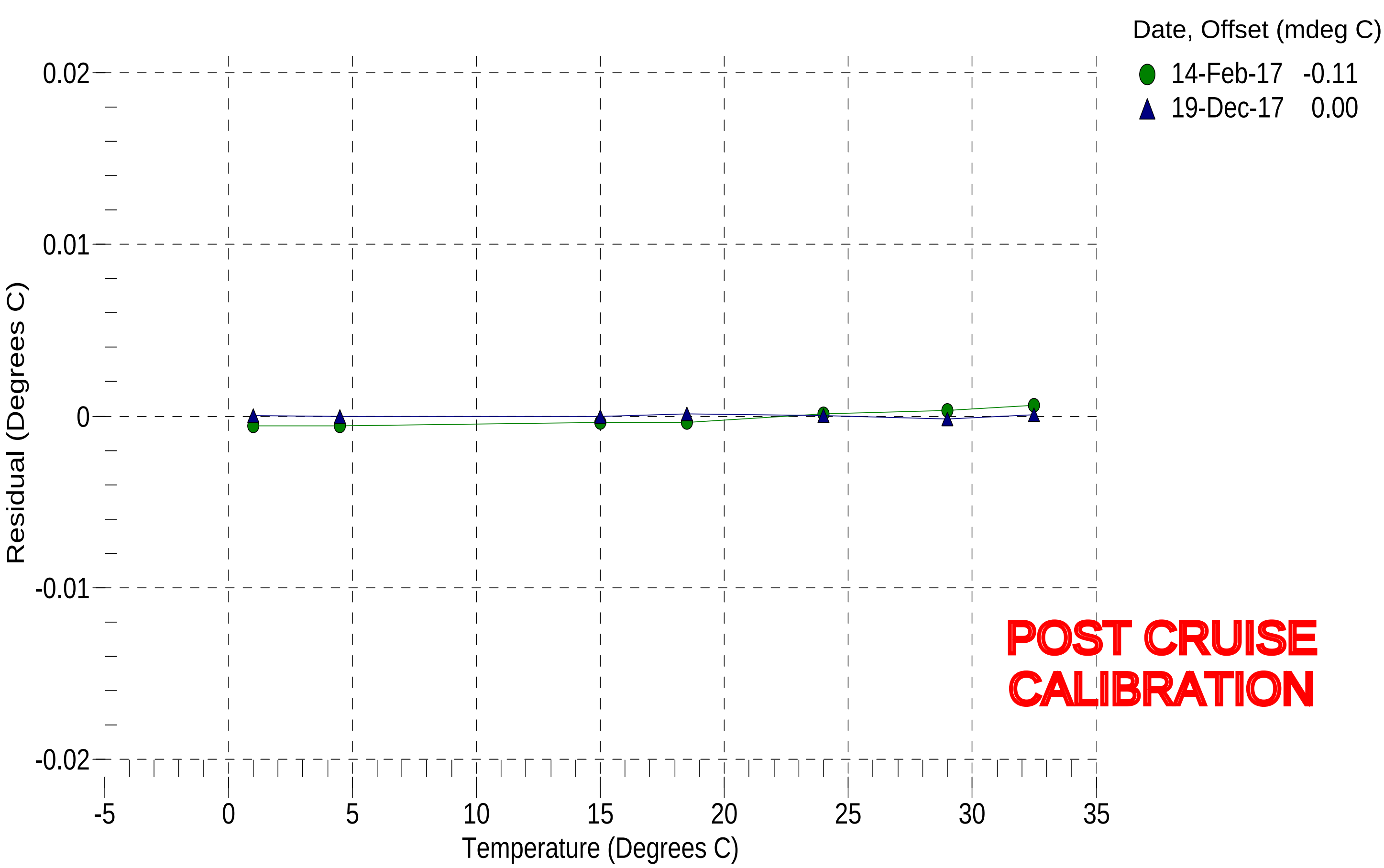
COEFFICIENTS:
a0 = 5.242107e-005
a1 = 2.651814e-004
a2 = -1.805759e-006
a3 = 1.328341e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 775027.2 | 1.0000 | 0.0000 |
| 4.4999 | 661001.4 | 4.4999 | -0.0000 |
| 15.0000 | 418251.9 | 15.0000 | -0.0000 |
| 18.4999 | 361334.2 | 18.5000 | 0.0001 |
| 24.0000 | 288860.4 | 24.0000 | 0.0000 |
| 29.0000 | 237121.6 | 28.9998 | -0.0002 |
| 32.5000 | 207212.4 | 32.5001 | 0.0001 |

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



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SENSOR SERIAL NUMBER: 0491
CALIBRATION DATE: 09-Jan-18

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

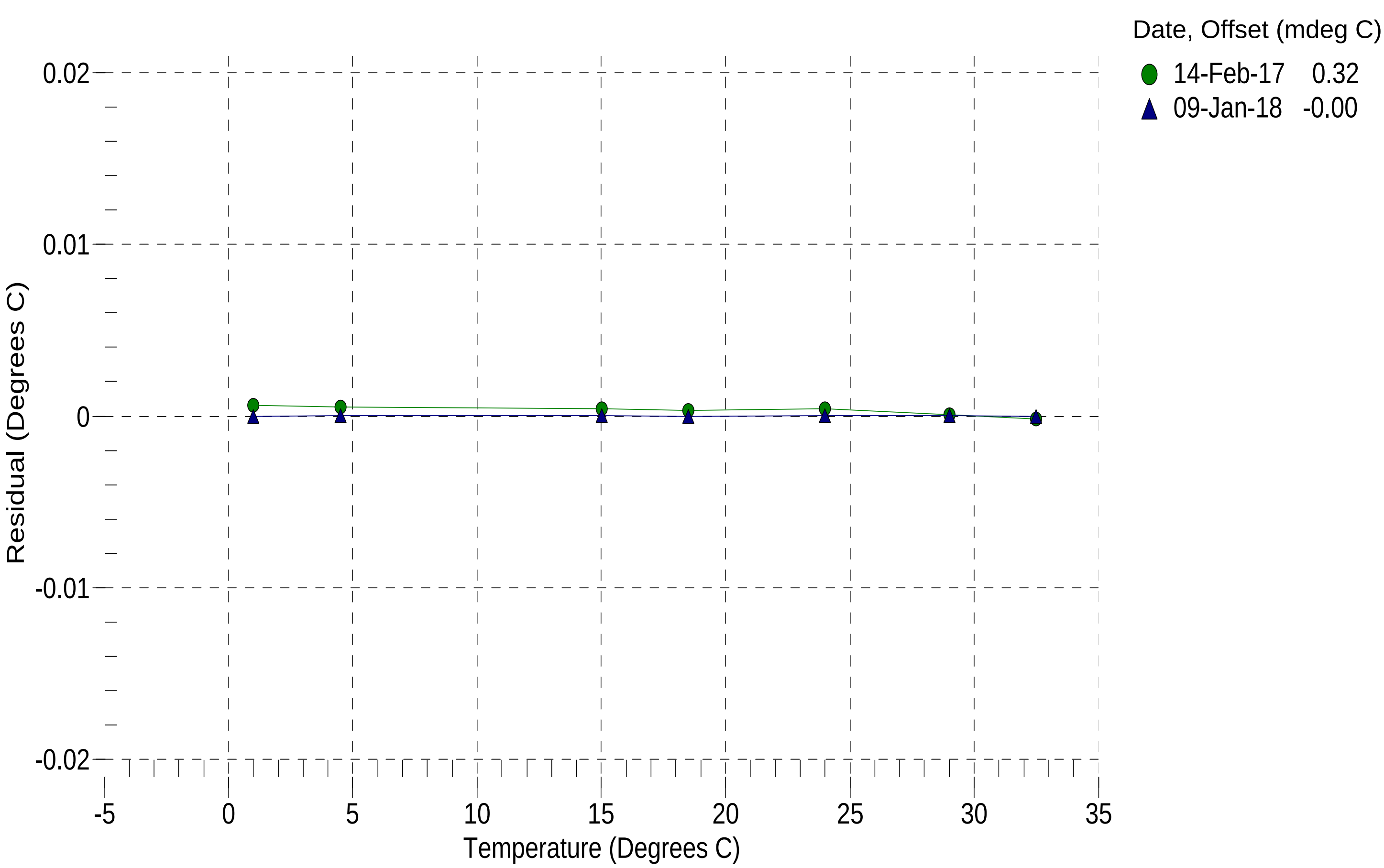
COEFFICIENTS:
a0 =  9.178931e-005
a1 =  2.562145e-004
a2 = -1.124566e-006
a3 =  1.155697e-007

| BATH TEMP (° C) | INSTRUMENT OUTPUT (counts) | INST TEMP (° C) | RESIDUAL (° C) |
|---|---|---|---|
| 1.0000 | 775071.2 | 1.0000 | -0.0000 |
| 4.5000 | 661027.7 | 4.5000 | 0.0000 |
| 15.0000 | 418265.2 | 15.0000 | 0.0000 |
| 18.5000 | 361345.2 | 18.5000 | -0.0000 |
| 24.0000 | 288864.2 | 24.0000 | 0.0000 |
| 29.0000 | 237117.5 | 29.0000 | 0.0000 |
| 32.5000 | 207207.0 | 32.5000 | -0.0000 |

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[\mathit{ln}(n)] + a2[\mathit{ln}^2(n)] + a3[\mathit{ln}^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



The original manufacture warranty on your instrument has expired. However, we are pleased to provide you with our 12 month Service Warranty on your instrument, which is renewed each time you return the device for service.

**Service Warranty Policy**

The instrument detailed below is returned to you after Service with a Limited 12 Month Warranty against defects in materials and workmanship, valid from the date of despatch from Valeport's premises, with the following exclusions, exceptions and limitations:

1) Sensors supplied by other manufacturers (including pressure sensors) are only warranted according to the warranty period provided by the original manufacturer (typically 1 year), and are thus excluded from this Warranty.
2) Consumable items (including, but not limited to: batteries, o-rings, zinc anodes and electrolytes) are not covered by warranty.
3) Reasonable wear and tear (as judged by Valeport) is not covered by warranty.
4) Valeport Limited shall be under no liability for any consequential loss or damage of any kind whatsoever.
5) Correctly performed standard maintenance procedures as described in the operating manual will not invalidate the warranty. Failures caused by improper care and handling, or by unskilled or poor quality repair and maintenance attempts are not covered under warranty. Modifications to the original design will invalidate the warranty, insofar as it relates to the modified part.
6) All warranty repairs must be performed by Valeport personnel or their authorized representatives.
7) Valeport Limited is the sole judge of the cause of any failure, and the validity of any warranty claim. Please refer to the "Spirit of the Warranty" section below.

- Goods for warranty assessment should be adequately packed (preferably in the original packing) and returned freight pre-paid to Valeport, complete with a description of the nature of the problem. It is preferable that an RMA (Returns Number) is obtained from us in advance, to allow us to schedule the repair.
- All warranty claims are assessed on a case-by-case basis. You will be informed as soon as possible as to the validity of the warranty claim.
- In the event of a valid warranty claim, the goods will be repaired or replaced as appropriate at the sole discretion of Valeport Limited. The repaired / replacement instrument will be returned to you at our cost, using our choice of shipping method.
- In the event of an invalid warranty claim, you will be informed of any repairs that are necessary, and if acceptable, the instrument will be repaired as if it had been returned for service, with appropriate costs and return freight charges payable by you.
- Any repairs made under warranty shall have no effect on the duration of the warranty period, i.e. the warranty shall continue as if no fault had occurred.
- Valeport may, at our discretion, opt to despatch a replacement part for fitting in the field, if it is deemed to be the most appropriate response. In such circumstances, the user will be required to return the faulty part to Valeport (at the user's cost) for assessment and confirmation that the failure is a valid warranty claim. Failure to return the faulty part, or if the fault is subsequently judged to fall outside the terms of the warranty, shall result in the user being invoiced for the replacement part and freight costs.

**Spirit of the Warranty**

This warranty is offered on the basis that Valeport fully expects the instrument to perform satisfactorily for many years. We have built a reputation on reliability, longevity and quality, and therefore the aim of this warranty is your satisfaction and peace of mind. The "rules" as detailed above are the framework within which we operate our warranty policy, and the minimum that you can expect from us in resolving any warranty issue. However, each case is considered on its own merit, and we may decide that in certain circumstances, alternative arrangements or solutions to a warranty issue are appropriate. Equally, we hope that our customers accept this warranty in the spirit in which it is given, and to respect that whilst our primary concern is always to try and ensure that any issues are resolved as quickly and as satisfactorily as possible, we do also have a responsibility to objectively assess the validity of any warranty claim, and to consider the interests of Valeport Limited in any actions taken.

M. Quartley

Matthew Quartley
*Managing Director*

**Instrument Type** **Modus SVS**

**Serial Number(s)** **33711**

**Pressure Test** **10 Bar**

**Date of Despatch** 14/12/2016

**Valeport Limited**, St. Peter's Quay, Totnes, Devon, TQ9 5EW. U.K.
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E-mail: sales@valeport.co.uk Web: www.valeport.co.uk

VAT No: GB 430 4453 84 Registered in England No: 1950444

## Valeport Calibration Worksheet - 4008231B

## Sound Velocity

| | |
|---|---|
| Transducer Type, mm | 50 |
| Transducer Ser No | 52297 |
| PCB Type | 400 round |
| PCB Part No | 0400554 |
| PCB Ser No | 53049 |
| SV Firmware Version | 04007149B0 |
| FPGA Firmware Version | 0650714C |
| Module Number | 12 |

### As Received Spot Check

| | SOS from unit | SOS from Standard | Error |
|---|---|---|---|
| Fresh | 1410.925 | 1412.662 | -1.737 |
| Saline | # | # | #VALUE! |
| #VALUE! | | | |

| Temp °C90 | SoS m/s | Measured ToF nsec*100 | Calc ToF nsec*100 | Meas-Calc ToF nsec | STAB | Half path mm | Total path mm |
|---|---|---|---|---|---|---|---|
| Low Temperature | | | | | | | |
| 2.0894 | 1412.664 | 7447432 | 7078825 | 3686.07 | | 50 | 100 |
| 2.0893 | 1412.663 | 7447438 | 7078827 | 3686.11 | STAB | 50 | 100 |
| 2.0896 | 1412.665 | 7447433 | 7078820 | 3686.13 | | 50 | 100 |
| # | #VALUE! | # | #VALUE! | #VALUE! | | 50 | 100 |
| # | #VALUE! | # | #VALUE! | #VALUE! | | 50 | 100 |
| High Temperature | | | | | | | |
| 15.9095 | 1469.091 | 7176304 | 6806931 | 3693.73 | | 50 | 100 |
| 15.9092 | 1469.090 | 7176315 | 6806936 | 3693.79 | | 50 | 100 |
| 15.9094 | 1469.091 | 7176311 | 6806933 | 3693.78 | STAB | 50 | 100 |
| # | #VALUE! | # | #VALUE! | #VALUE! | | 50 | 100 |
| # | #VALUE! | # | #VALUE! | #VALUE! | | 50 | 100 |

| Enter Last 6 bytes of characterisation string |
|---|
| 7 |
| 10 |
| 10 |
| 8 |
| 4 |
| -3 |
| |
| Characterised OK |

| Return Signal Voltage |
|---|
| 700mV |

### Stage 1: First order fit

| Temp °C90 | SoS from Bilaniuk & Wong m/s | Measured ToF nsec*100 | Coefficients | Calc SoS from coefficients m/s | Error (Calc - True) m/s | Acceptable Error m/s | Pass/Fail |
|---|---|---|---|---|---|---|---|
| 2.0893 | 1412.663 | 7447438 | 3.885920E+05 | 1412.663 | 0.000 | ±0.001 | Pass |
| 15.9094 | 1469.091 | 7176311 | 1.002831E+07 | 1469.090 | 0.000 | ±0.001 | Pass |

### Stage 2: Enter calibration string

#024;12;1;15;0;0;0;0;1.002831E+07;3.885920E+05

### Stage 3: Check point

| Temp °C90 | Actual SoS m/s | Measured SoS m/s | Error SoS Reading-Actual m/s | Acceptable Error m/s | Pass/Fail |
|---|---|---|---|---|---|
| 15.9094 | 1469.091 | 1469.092 | 0.001 | ±0.005 | Pass |

### Stage 4: Reference Check

| Reference SoS m/s | Sensor SoS m/s | Error SoS Reading-Actual m/s | Acceptable Error m/s | Pass/Fail |
|---|---|---|---|---|
| # | # | #VALUE! | ±0.010 | #VALUE! |

| | |
|---|---|
| Name: | R Musgrove |
| Date: | 14/12/2016 |
| Signature: | |

# VALEPORT

**This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to UKAS or National Standards.**

| | |
|---|---|
| **Calibration Certificate Number:** | **47566** |
| **Instrument Type:** | **Tidemaster** |
| **Instrument Serial Number:** | **33711** |
| **Calibrated By:** | **R.Musgrove** |
| **Date:** | **14/12/2016** |
| **Signed:** | |

**Full details of the results from the calibration procedure applied to each fitted sensor are available, on request, via email. This summary certificate should be kept with the instrument.**

Valeport Ltd | St Peter's Quay | Totnes | Devon | TQ9 5EW | UK
T: +44 (0) 1803 869292
E: sales@valeport.co.uk | www.valeport.co.uk

# Appendix 3:

# Vessel offset reports

Updated: 6/5/2018

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Ocean Service
National Geodetic Survey
Field Operations Branch

# Thomas Jefferson Launch 2903 Component Spatial Relationship Survey Field Report

Kevin Jordan
May 1, 2017

## PURPOSE

The intention of this survey was to accurately position the POS/MV IMU, GPS Antennas, Receiver and Transmitter, Side Scan Reference Marks and bench marks on TJ launch 2903.

## PROJECT DETAILS

This survey was conducted on May 1, 2017 at NOAA's Marine Operations Center in Norfolk, VA . The boat was on jack stands and leveled. The temperature was around 70 degrees and winds 10-15 mph.

## INSTRUMENTATION

The TOPCON GPT 3000 Series Theodolite was used to position all points on the launch.

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. 5.7.2

ForeSight DXM Ver. 3.2.2 was used for post processing.

## PERSONNEL

| | | |
|---|---|---|
| Kevin Jordan | NOAA/NOS/NGS/Field Operations Branch | 757-441-5467 |
| Jim Harrington | NOAA/NOS/NGS/Field Operations Branch | 757-441-5496 |
| Ryan Hippenstiel | NOAA/NOS/NGS/Field Operations Branch | 757-441-6595 |

**Temporary Control**

A network of temporary control was established on the lot consisting or two marks set on solid ground about 60 meters apart. These points were named TP 1 and TP 2. The majority of observations were performed using one setup on TP 1. TP 2 was utilized to setup the instrument and observe two additional points on the hull of the boat.

OBSERVED POINTS

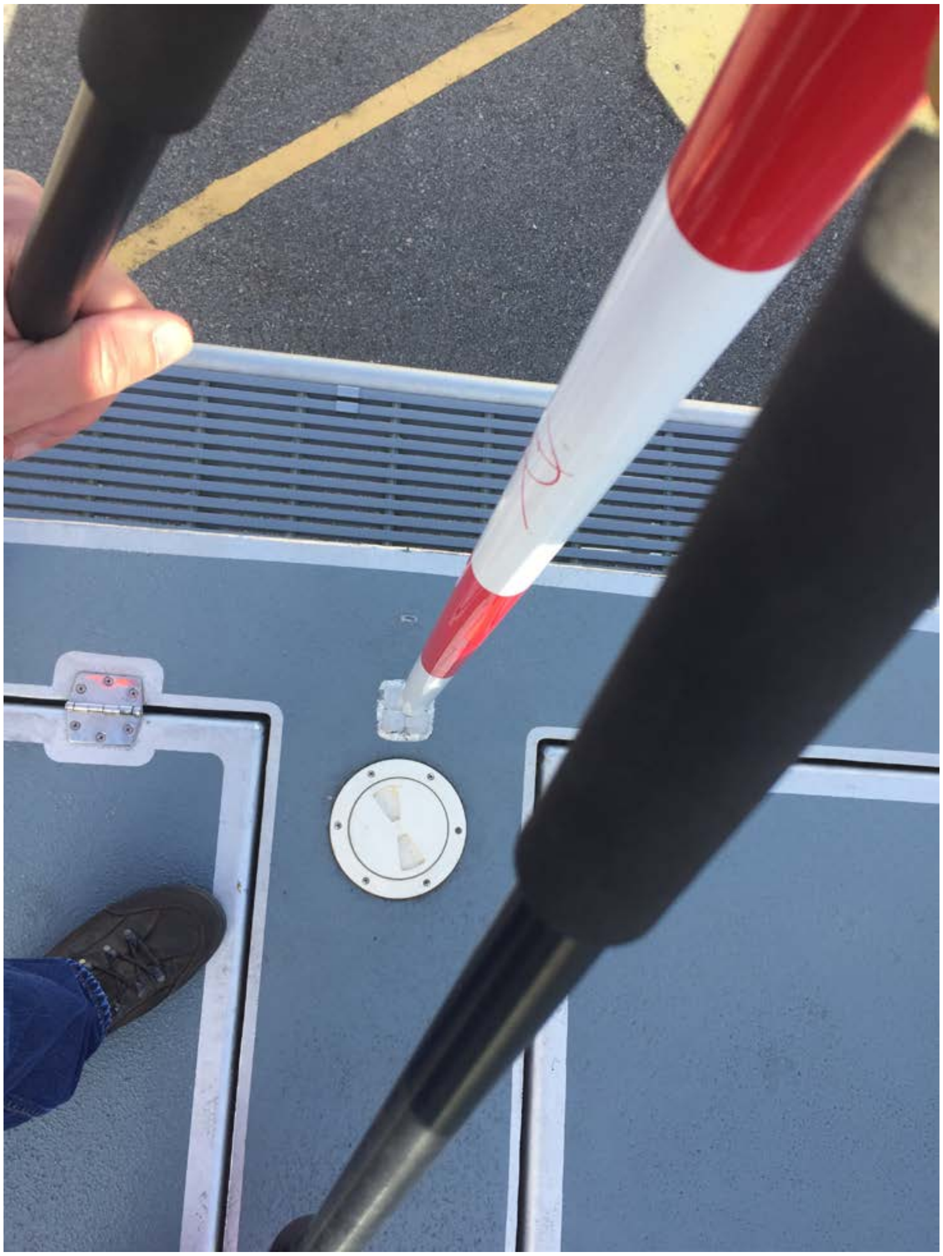
IMU

CL 1

CL 2

CL 3

CL 4



BM PORT 3

BM PORT 2

BM PORT 1

BM STAR 3

BM STAR 2

BM STAR 1

GPS PORT ARP

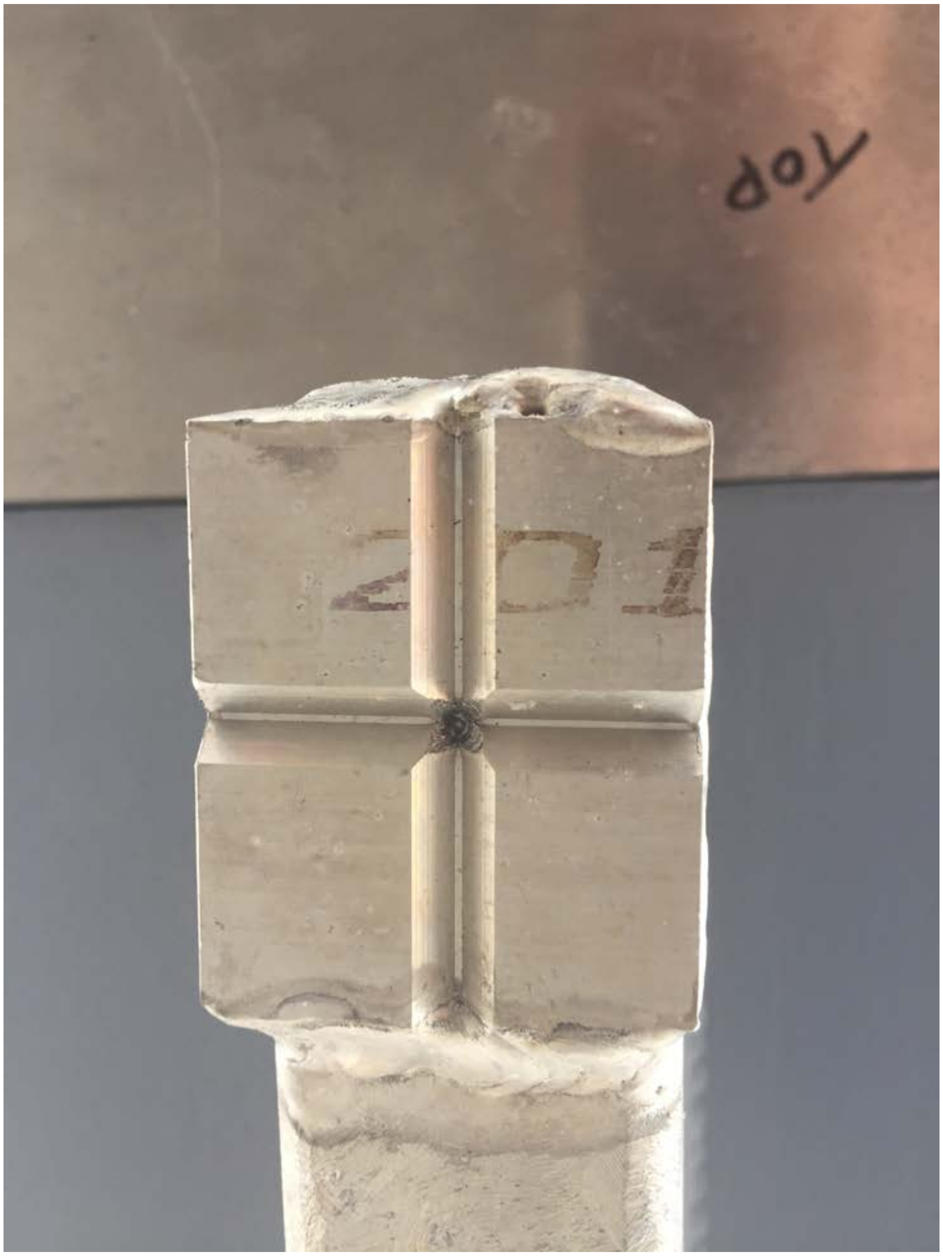
GPS STAR ARP

SIDE SCAN TOW POINT RM

RECEIVER

TRANSMITTER

KEEL BM FWD

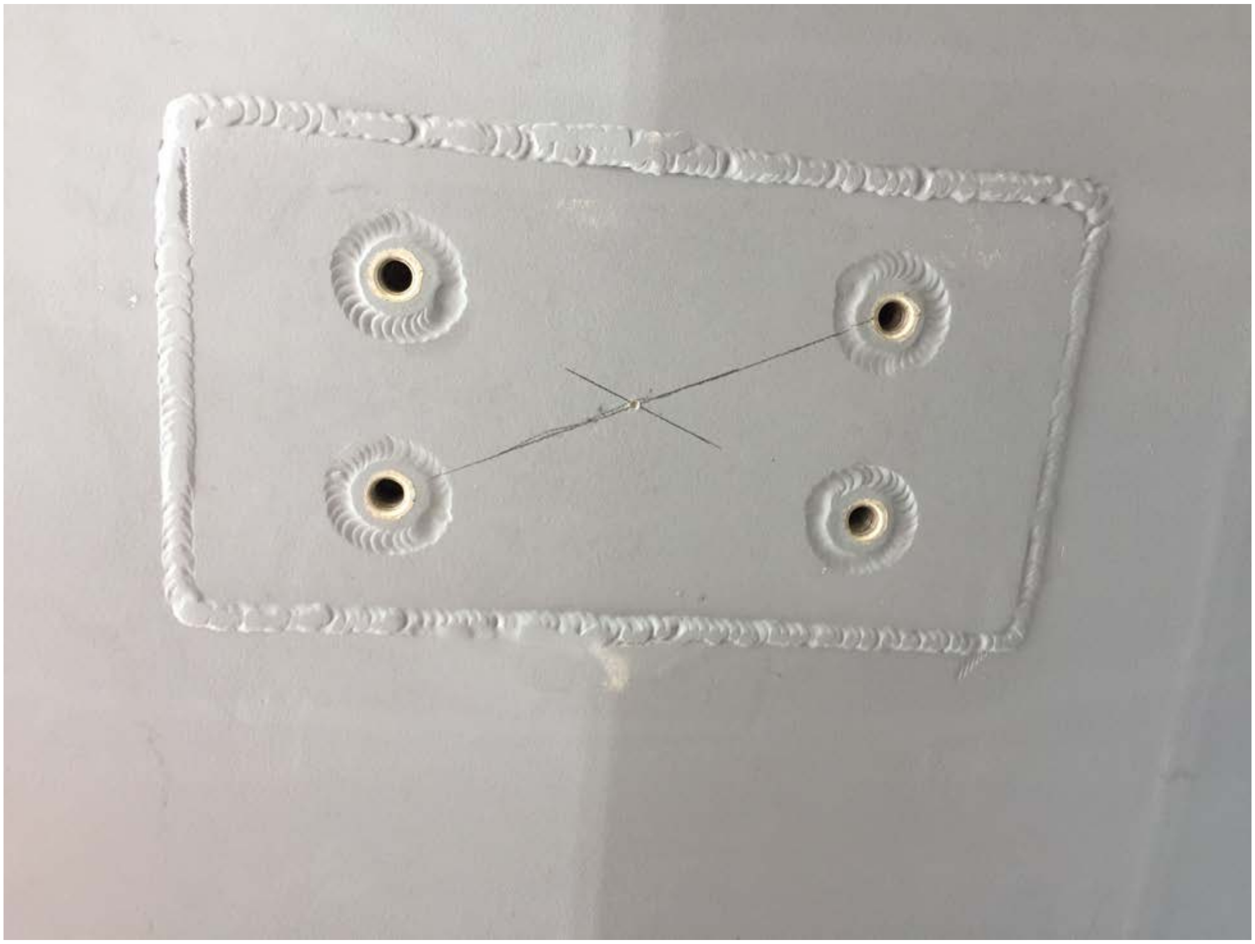


KEEL BM AFT

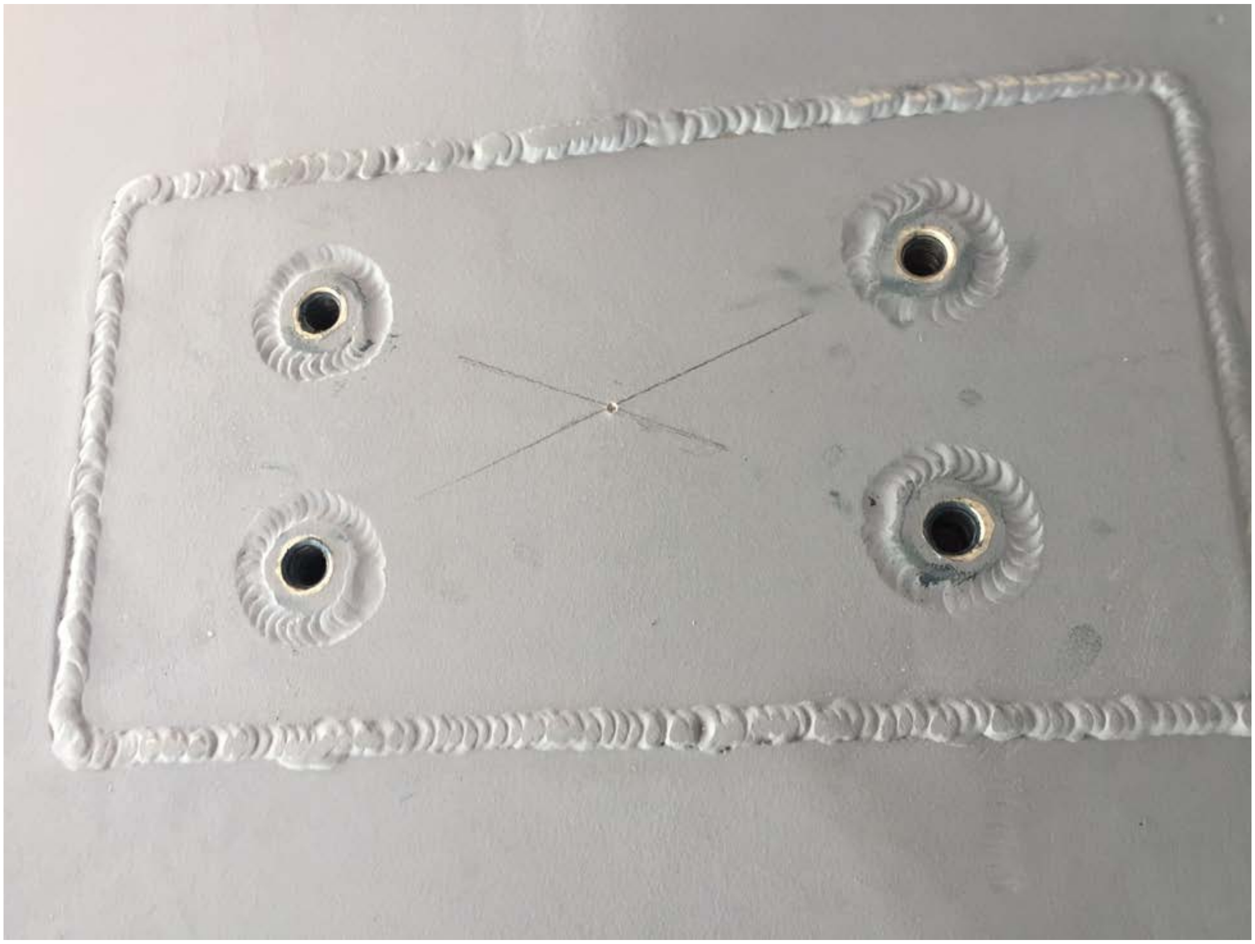
PORT SIDE SCAN HARD POINT FWD

PORT SIDE SCAN HARD POINT AFT

STAR SIDE SCAN HARD POINT FWD



STAR SIDE SCAN HARD POINT AFT



**POST PROCESSING**

The collected points were surveyed in an assumed coordinate system and needed to be translated to the point "IMU" as X=0, Y=0, Z=0. The azimuth from CL 4 to CL 1 needed to be oriented to 0° 00' 00". Post Processing was performed using ForeSight DXM to produce the following Coordinate Report. The X Axis is Positive toward the Bow. The Y Axis is positive toward the Starboard side. The Z Axis is positive downward.

**Transmitter center**

The transmitter center was determined by measuring the length and width of the face (fwd to aft, port to starboard) and splitting the difference of the measurement. A temporary mark was placed on a piece of masking tape and measured.

**Side Scan Tow Point Reference Mark**

A reference mark for the Side Scan Sonar was established as part of this survey. The point of measurement can be described as a "." punch mark below the port-facing middle bracket on the side-scan arm.

## Final Coordinate List

An excel spreadsheet labeled TJ_2903.xlsx is included with the project submission. Below is a report of the final coordinate listing.

**2903 Boat Survey 2017**

| NAME | X (METERS) | Y (METERS) | Z (METERS) |
|---|---|---|---|
| IMU | 0.000 | 0.000 | 0.000 |
| CL1 | 3.591 | 0.002 | -1.322 |
| CL3 | -0.212 | 0.012 | -0.657 |
| CL2 | -0.145 | 0.029 | -2.651 |
| CL4 | -4.020 | 0.002 | -0.742 |
| BM PORT 3 | -1.581 | -0.618 | -2.671 |
| BM PORT 2 | -0.702 | -0.467 | -3.043 |
| BM PORT 1 | 0.174 | -1.424 | -1.069 |
| BM STAR 3 | -1.581 | 0.692 | -2.667 |
| BM STAR 2 | -0.698 | 0.509 | -3.046 |
| BM STAR 1 | 0.170 | 1.440 | -1.052 |
| GPS PORT ARP | -0.693 | -0.710 | -3.572 |
| GPS STAR ARP | -0.680 | 0.746 | -3.579 |
| SIDE SCAN TOW POINT RM | -5.307 | -0.015 | -3.121 |
| RECEIVER | 0.263 | 0.000 | 0.530 |
| TRANSMITTER | 0.044 | -0.005 | 0.532 |
| KEEL BM FWD | 0.455 | 0.001 | 0.632 |
| KEEL BM AFT | -0.577 | 0.002 | 0.716 |
| PORT SIDE SCAN HARD POINT FWD | 1.102 | -0.561 | 0.303 |
| PORT SIDE SCAN HARD POINT AFT | 0.188 | -0.566 | 0.307 |
| STAR SIDE SCAN HARD POINT FWD | 1.105 | 0.554 | 0.322 |
| STAR SIDE SCAN HARD POINT AFT | 0.195 | 0.572 | 0.319 |

***NOTE Z VALUES ARE POSITIVE DOWNWARD**

**SURVEY CLOSURE**
The majority of points were established by occupying a temporary mark (TP 1) established on solid ground about 11 meters behind the stern of the boat. Throughout the survey, Horizontal and Vertical checks were made to the 2$^{nd}$ temporary point that was established on the lot (TP 2). At the end of the observations, a check point was collected and an inverse was computed.

TP 2
$\Delta$ X = 0.001 m
$\Delta$ Y = 0.003 m
$\Delta$ Z = 0.005 m

A second setup was required to collect two additional points. The instrument was setup on TP 2 and backsight TP 1. The initial survey setup checked TP 1 by:

CK TP 1
$\Delta$ X = 0.001 m
$\Delta$ Y = 0.000 m
$\Delta$ Z = 0.003 m

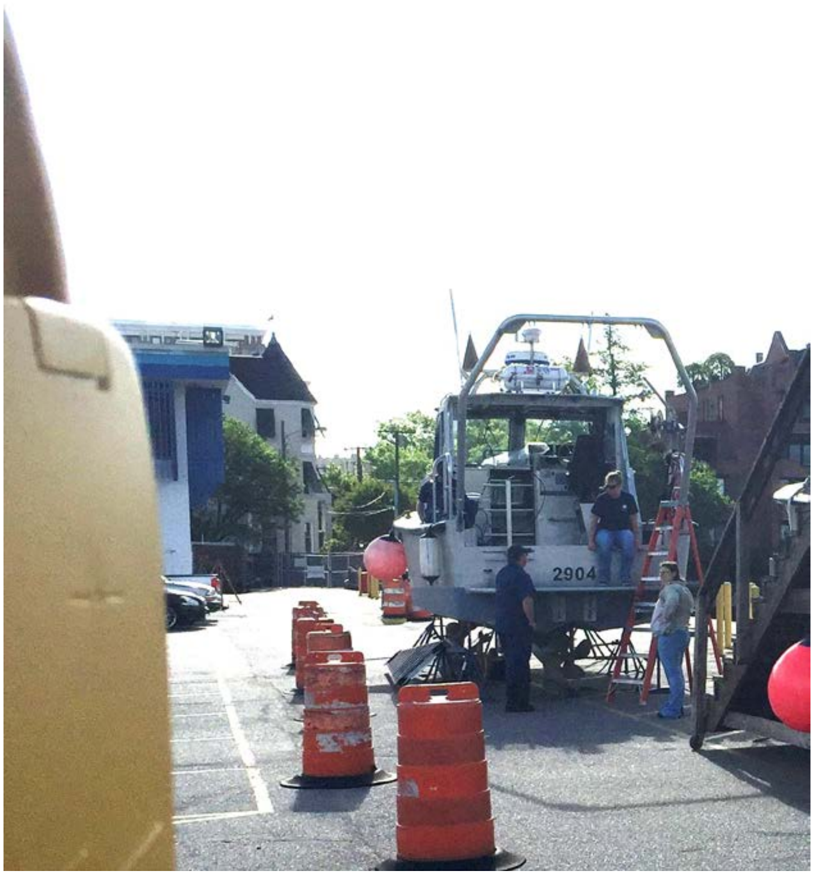
Following the collection of the additional points, a final check to TP 1 was performed and closure was:

CK TP 1
$\Delta$ X = 0.001 m
$\Delta$ Y = 0.001 m
$\Delta$ Z = 0.001 m

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Ocean Service
National Geodetic Survey
Field Operations Branch

# Thomas Jefferson Launch 2904
# Component Spatial Relationship Survey
# Field Report

Kevin Jordan
May 1, 2017



## PURPOSE

The intention of this survey was to accurately position the POS/MV IMU, GPS Antennas, Receiver and Transmitter, Side Scan Reference Marks and bench marks on TJ launch 2904.

## PROJECT DETAILS

This survey was conducted on May 1, 2017 at NOAA's Marine Operations Center in Norfolk, VA . The boat was on jack stands and leveled. The temperature was around 70 degrees and winds 10-15 mph.

## INSTRUMENTATION

The TOPCON GPT 3000 Series Theodolite was used to position all points on the launch.

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. 5.7.2

ForeSight DXM Ver. 3.2.2 was used for post processing.

## PERSONNEL

| | | |
|---|---|---|
| Kevin Jordan | NOAA/NOS/NGS/Field Operations Branch | 757-441-5467 |
| Jim Harrington | NOAA/NOS/NGS/Field Operations Branch | 757-441-5496 |
| Ryan Hippenstiel | NOAA/NOS/NGS/Field Operations Branch | 757-441-6595 |

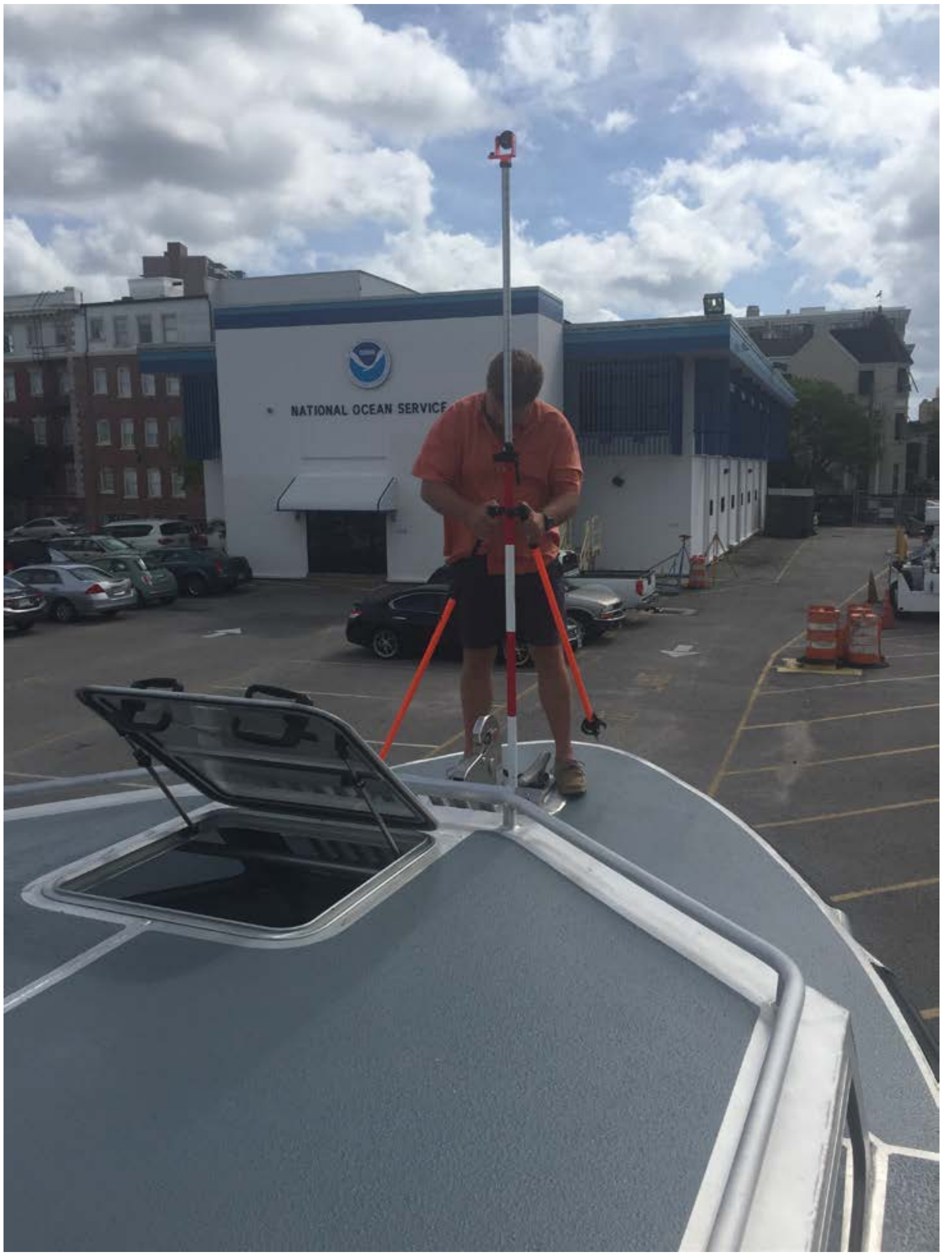
**Temporary Control**

A network of temporary control was established on the lot consisting or two marks set on solid ground about 60 meters apart.  These points were named TP 1 and TP 2.  The majority of observations were performed using one setup on TP 1.  TP 2 was utilized to setup the instrument and observe two additional points on the hull of the boat.

OBSERVED POINTS

IMU

CL 1



CL 2

CL 3

CL 4

BM PORT 3

BM PORT 2

BM PORT 1

BM STAR 3

BM STAR 2

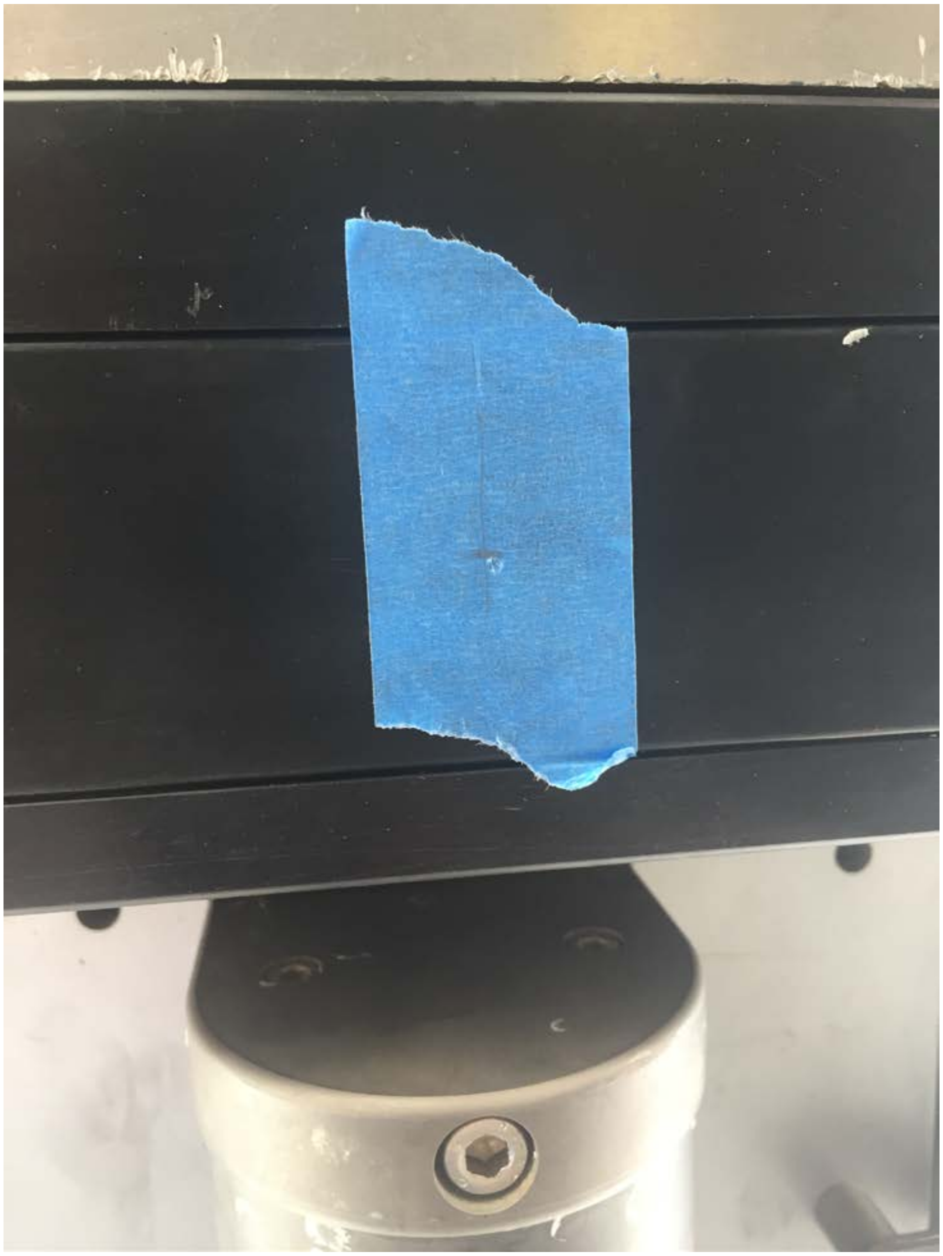
BM STAR 1

GPS PORT ARP

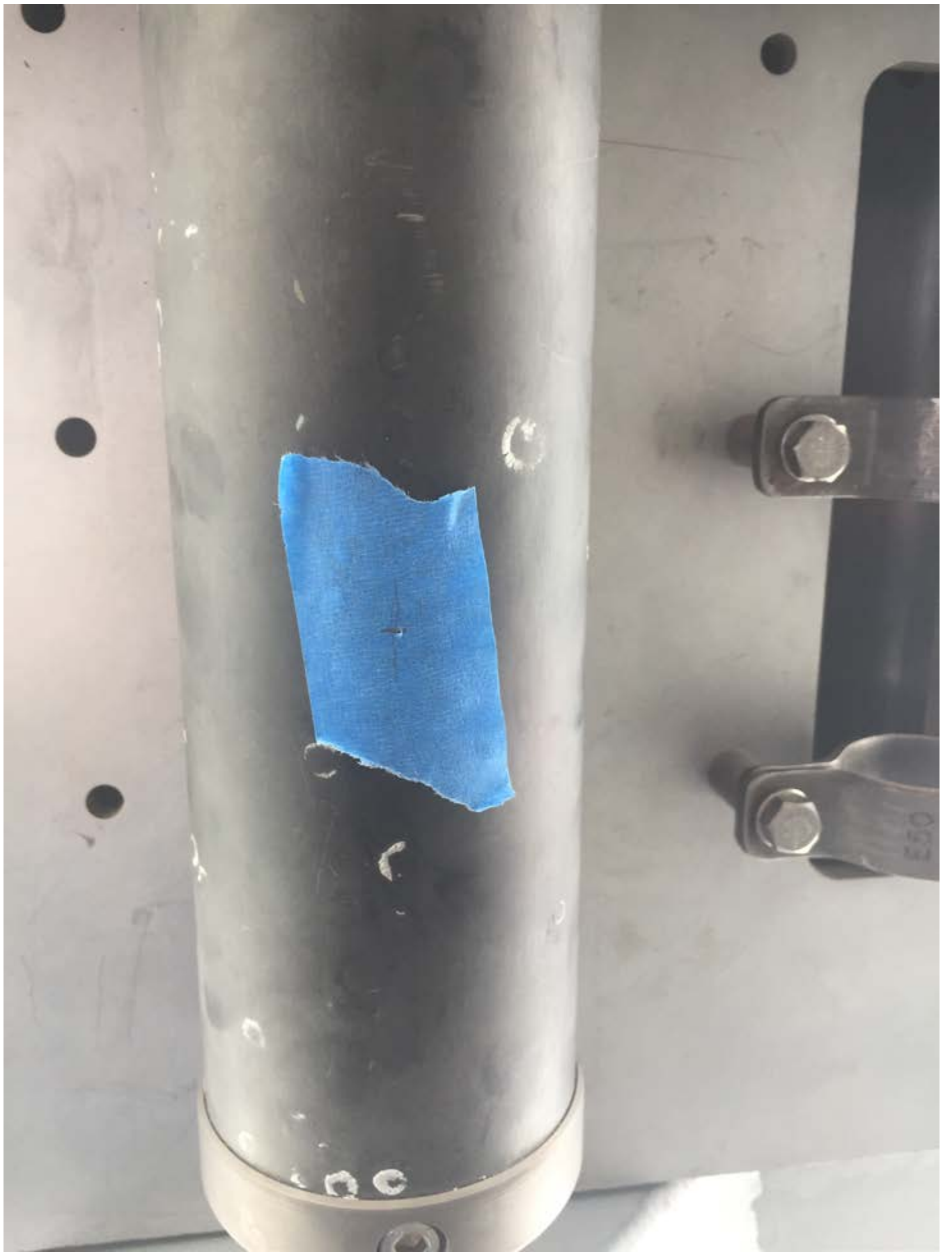
GPS STAR ARP

SIDE SCAN TOW POINT RM

RECEIVER



TRANSMITTER



KEEL BM FWD

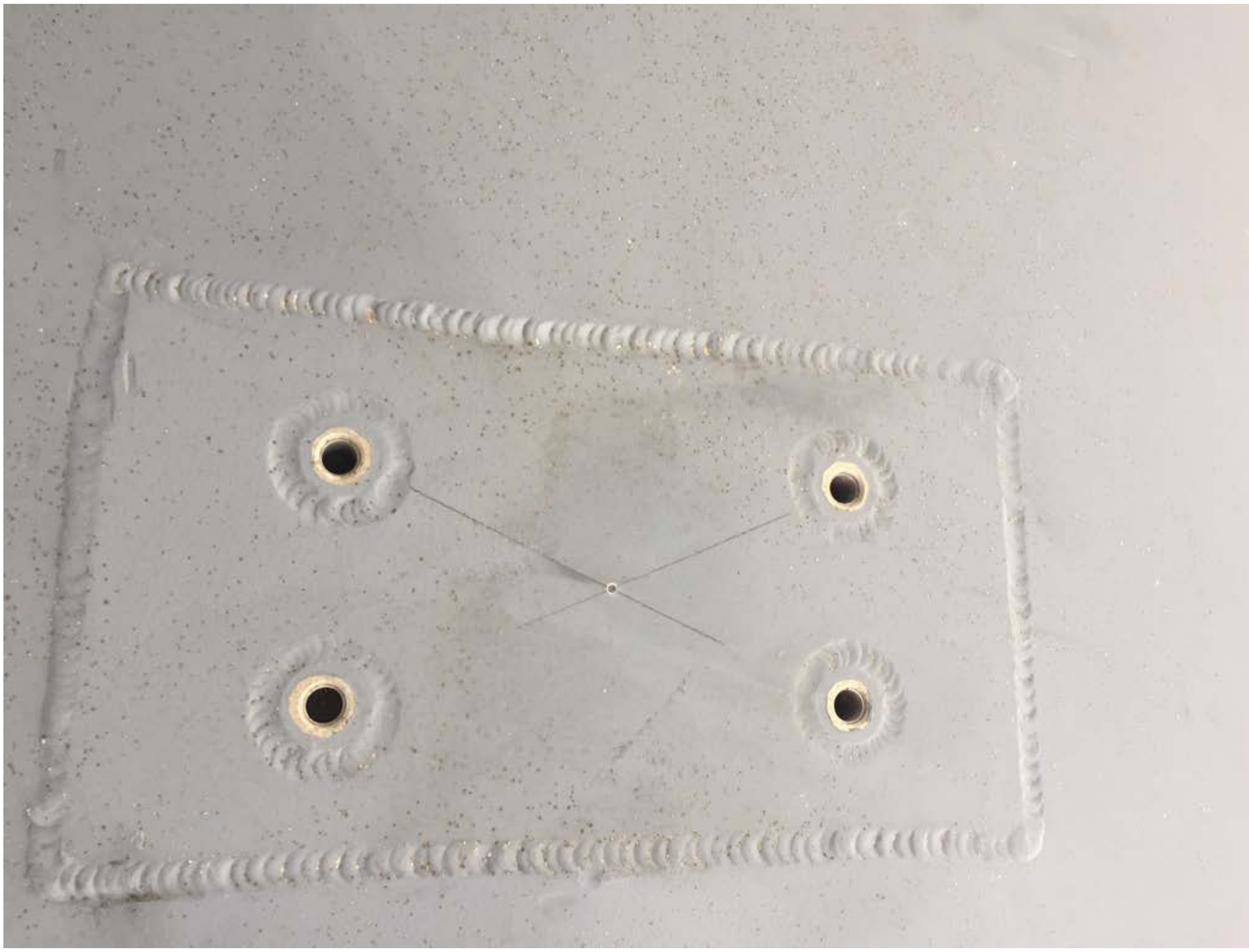
KEEL BM AFT

PORT SIDE SCAN HARD POINT FWD

PORT SIDE SCAN HARD POINT AFT

STAR SIDE SCAN HARD POINT FWD

STAR SIDE SCAN HARD POINT AFT



**POST PROCESSING**

The collected points were surveyed in an assumed coordinate system and needed to be translated to the point "IMU" as X=0, Y=0, Z=0. The azimuth from CL 4 to CL 1 needed to be oriented to 0° 00' 00". Post Processing was performed using ForeSight DXM to produce the following Coordinate Report. The X Axis is Positive toward the Bow. The Y Axis is positive toward the Starboard side. The Z Axis is positive downward.

**Transmitter center**

The transmitter center was determined by measuring the length and width of the face (fwd to aft, port to starboard) and splitting the difference of the measurement. A temporary mark was placed on a piece of masking tape and measured.

## Side Scan Tow Point Reference Mark

A reference mark for the Side Scan Sonar was established as part of this survey. The point of measurement can be described as a "." punch mark on the left-most middle bracket and is aft-facing on the side-scan arm.

## Final Coordinate List

An excel spreadsheet labeled TJ_2904.xlsx is included with the project submission. Below is a report of the final coordinate listing.

**2904 Boat Survey 2017**

| NAME | X (METERS) | Y (METERS) | Z (METERS) |
|---|---|---|---|
| IMU | 0.000 | 0.000 | 0.000 |
| CL1 | 3.583 | -0.011 | -1.358 |
| CL3 | -0.212 | -0.004 | -0.649 |
| CL2 | -0.171 | -0.011 | -2.653 |
| CL4 | -4.014 | -0.012 | -0.686 |
| BM PORT 3 | -1.598 | -0.678 | -2.648 |
| BM PORT 2 | -0.738 | -0.549 | -3.040 |
| BM PORT 1 | 0.185 | -1.453 | -1.052 |
| BM STAR 3 | -1.607 | 0.649 | -2.649 |
| BM STAR 2 | -0.743 | 0.533 | -3.041 |
| BM STAR 1 | 0.146 | 1.434 | -1.060 |
| GPS PORT ARP | -0.725 | -0.762 | -3.562 |
| GPS STAR ARP | -0.730 | 0.726 | -3.567 |
| SIDE SCAN TOW POINT RM | -5.477 | -0.061 | -3.035 |
| RECEIVER | 0.269 | -0.007 | 0.529 |
| TRANSMITTER | 0.050 | 0.000 | 0.535 |
| KEEL BM FWD | 0.467 | 0.003 | 0.631 |
| KEEL BM AFT | -0.570 | 0.003 | 0.735 |
| PORT SIDE SCAN HARD POINT FWD | 1.130 | -0.563 | 0.301 |
| PORT SIDE SCAN HARD POINT AFT | 0.209 | -0.563 | 0.314 |
| STAR SIDE SCAN HARD POINT FWD | 1.123 | 0.579 | 0.300 |
| STAR SIDE SCAN HARD POINT AFT | 0.195 | 0.568 | 0.312 |

***NOTE Z VALUES ARE POSITIVE DOWNWARD**

**SURVEY CLOSURE**
The majority of points were established by occupying a temporary mark (TP 1) established on solid ground about 20 meters behind the stern of the boat. Throughout the survey, Horizontal and Vertical checks were made to the 2nd temporary point that was established on the lot (TP 2). At the end of the observations, a check point was collected and an inverse was computed.

TP 2
$\Delta$ X = 0.000 m
$\Delta$ Y = 0.001 m
$\Delta$ Z = 0.003 m

A second setup was required to collect two additional points. The instrument was setup on TP 2 and backsight TP 1. The initial survey setup checked TP 1 by:

CK TP 1
$\Delta$ X = 0.001 m
$\Delta$ Y = 0.000 m
$\Delta$ Z = 0.003 m

Following the collection of the additional points, a final check to TP 1 was performed and closure was:

CK TP 1
$\Delta$ X = 0.001 m
$\Delta$ Y = 0.001 m
$\Delta$ Z = 0.001 m

NOAA THOMAS JEFFERSON (S 222)
SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY
JULY-AUGUST 2016

# FINAL REPORT

September 1, 2016 - Rev “1”


Prepared By:

The **IMTEC** Group, Ltd.
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**I**ndustrial **M**easurement **T**echnology **E**ngineering **C**onsultants

## *CONTENTS*



**ELECTRONIC FILES TRANSMITTED WITH THIS REPORT**

Raw Data-World.txt
Report Tables
- Kongsberg system.xlsx
- EM710TX system.xlxs
- IMU System.xlsx
- ORU System.xlsx

# PROJECT OVERVIEW

## Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

## General Comments

This report summarizes coordinate measurement data taken on the vessel NOAA Thomas Jefferson July 27 and 28, 2016 and August 22 thru 26, 2016. The vessel was located in a graving dock at US Coast Guard Yard, 2104 Hawkins Point Road, Baltimore, MD.

Coordinate measurements were taken to characterize the vessel and create the required reference coordinate system for reporting azimuth, pitch, roll and coordinate data.

Coordinate measurements were then taken to define elements and features according to the SOW MOA2-11(15) Dated December 8, 2015 and as requested by NOAA representatives in support of the EM710 Multi-Beam Sounding system transducer installation.

Locations of existing draft marks were measured and recorded.

## 3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face.

Temporary "benchmarks" or reference points were placed throughout the dry-dock area and on the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total station, S/N 110554 was calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center November 17, 2015.

## Reference Coordinate Systems

The following parameters were used to define the reference coordinate system for reporting the survey data per Kongsberg and NOAA representatives.

**Kongsberg requested vessel coordinate system:**

Origin: Top Dead Center (TDC) of the Inertial Measurement Unit (IMU):
X=0.000, Y=0.000, Z=0.000

Pitch and Azimuth:

Ten (10) Pairs of points were surveyed from approximately Frame 90 through Frame 10 on the Keel plate and then bisected to obtain a center point. These points were then projected onto the keel plane and used to construct a best fit line. A Best fit line faired through these points determined the ship system azimuth (X-Axis) and Pitch.

Roll: Six points were measured port/stbd, and fwd/aft and ~center port/stbd to determine the plane of the aft deck. This plane was used to establish roll.

Thus the vessel coordinate system is depicted as shown:

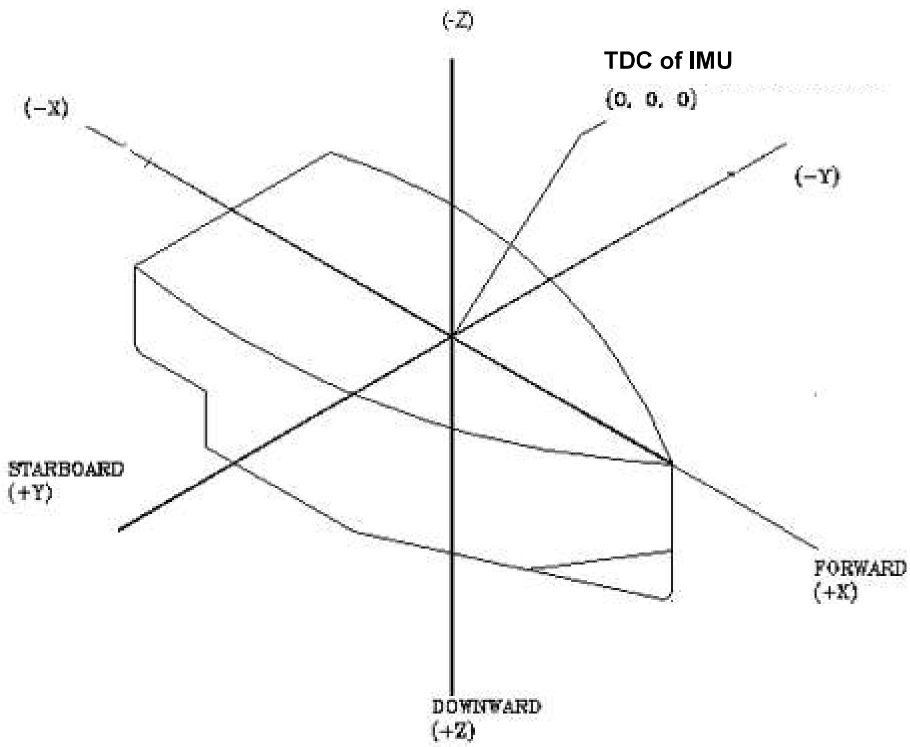



Figure 1 – Vessel Coordinate System

**The first coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | Center of TX Transducer Frame: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of TX Transducer Frame. |
| Roll: | Plane of TX Transducer Frame. |
| X Axis: | Azimuth of TX Transducer Frame X axis Positive Forward. |
| Z Axis: | Normal to Plane of TX Transducer Frame axis Positive towards keel |

The TX Frame therefore completely defines a vessel coordinate system.

**The second coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | TDC target on IMU: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of IMU |
| Roll: | Plane of IMU |
| X Axis: | Azimuth of IMU X axis Positive Forward |
| Z Axis: | Normal to Plane of IMU axis Positive Towards keel |

IMU therefore completely defines a vessel coordinate system.

**The third coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | TDC target on ORU: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of ORU |
| Roll: | Plane of ORU |
| X Axis: | Azimuth of ORU X axis Positive Forward |
| Z Axis: | Normal to Plane of ORU axis positive Towards keel |

ORU therefore completely defines a vessel coordinate system.

NOAA Representative requested that all survey data be presented in these coordinate systems including the draft marks.


Figure 2- Optical Reference Unit (ORU)

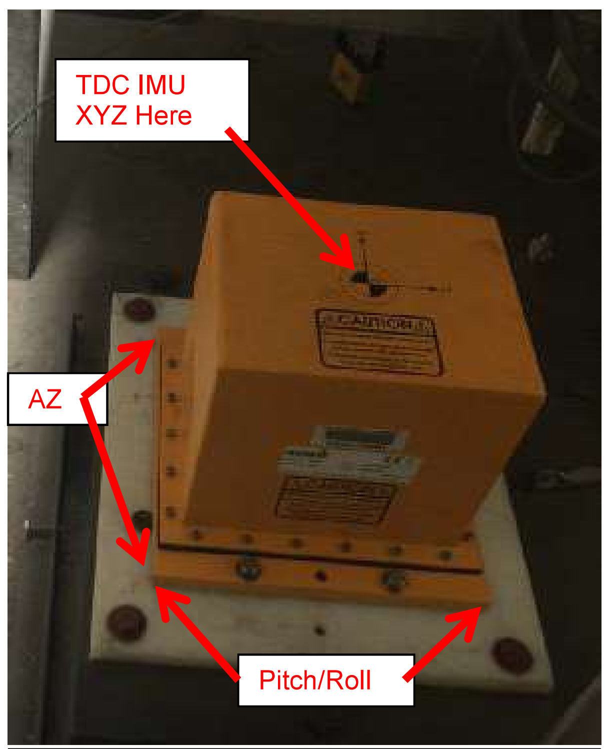



Figure 3- Inertial Measurement Unit (IMU)

## Measurement Procedure

Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets were frequently used as a temporary benchmark. The Sokkia NET 1200 total station operated through a notebook computer running Spatial Analyzer™ industrial measurement software was used to measure the targets and record observations.

## Gondola Installation

At the request of shipyard and NOAA personnel, IMTEC assisted with proper positioning of the gondola to within the azimuth, pitch and roll tolerances required by Kongsberg prior to welding.

## EM 710TX, EM 710RX and EM2040 Transducer Frames

After the transducer frames were installed, data points were surveyed at each of the bolt locations to determine overall flatness. Shim values were provided to Kongsberg to meet the flatness requirement. After shims were added and bolts final torqued, the frames were again surveyed to document final flatness. Final location (X, Y, Z), pitch, roll and azimuth of the Kongsberg transducers frames with respect to the vessel coordinate system were determined.

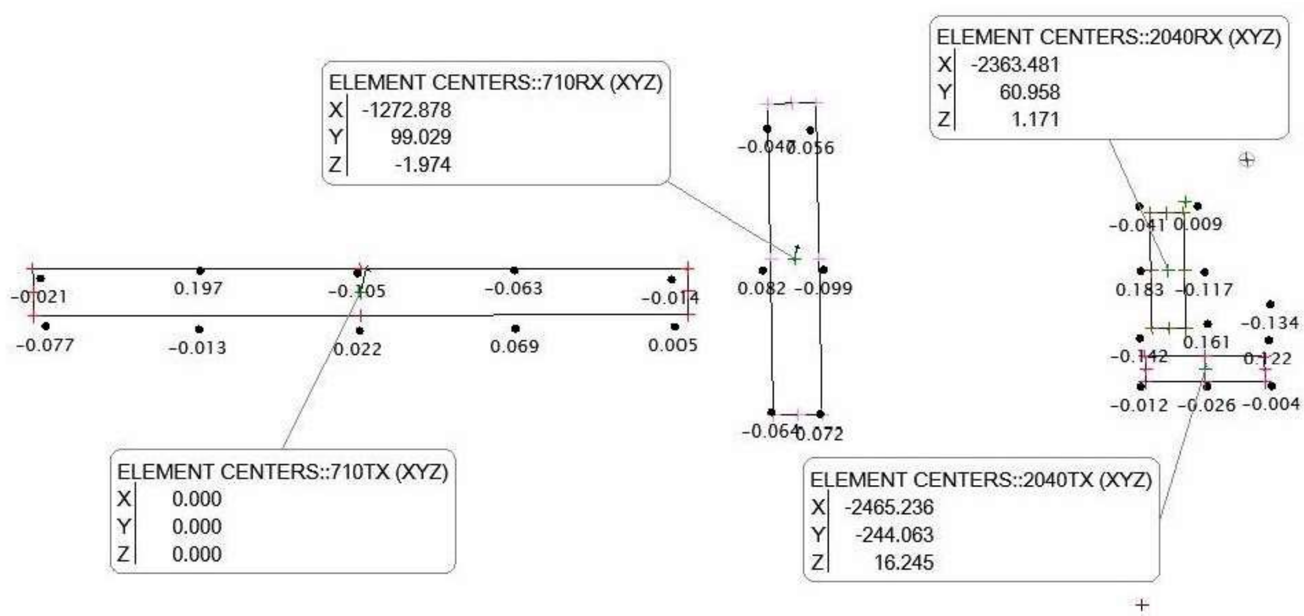



Figure 4-Flatness EM710 TX/RX and EM2040 TX/RX as Installed (mm)

## Vessel Benchmarks and Navigation Elements

Existing benchmarks and elements were surveyed as part of this effort and values for each are reported in the requested vessel orthogonal coordinate system. Additional benchmarks were added at the top of mast, at the starboard side of aft deck and at the top of the pilot house.

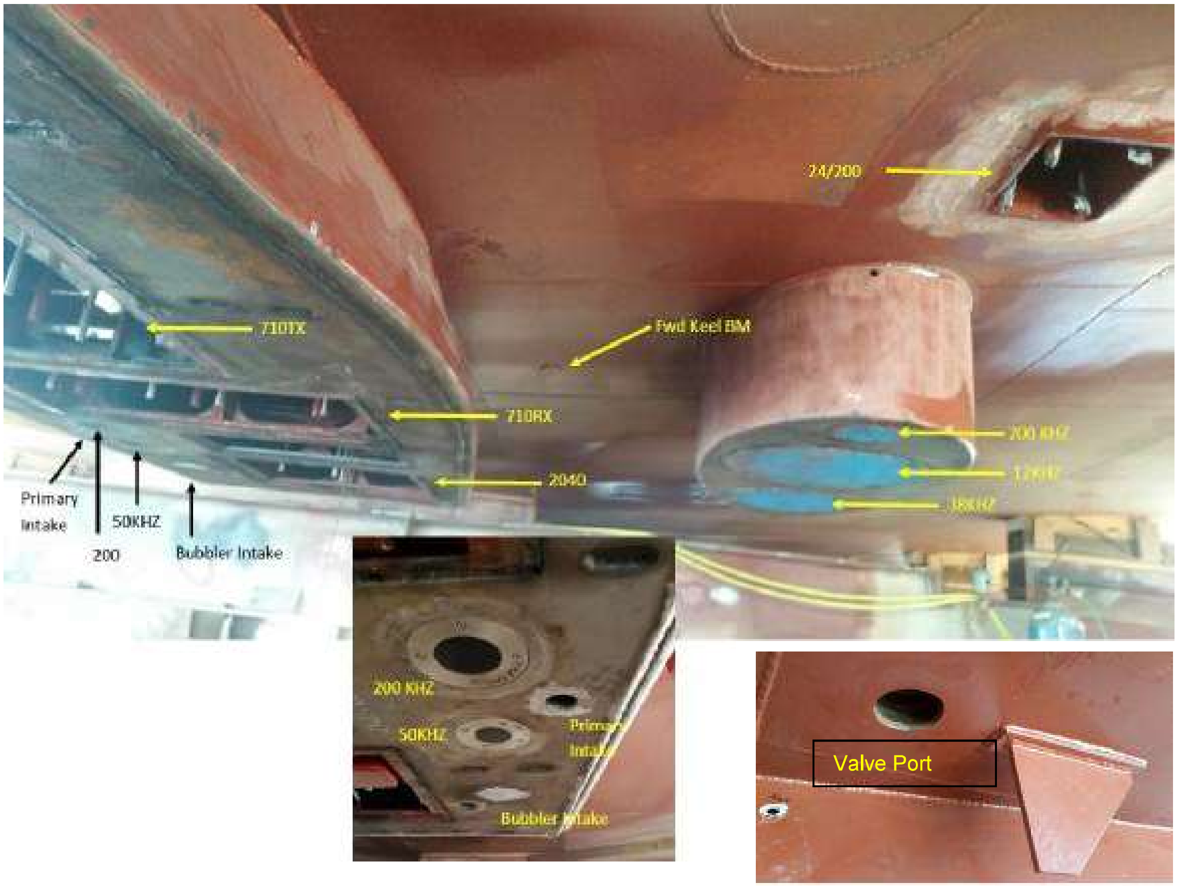



Figure 5-Elements at Bottom of Hull


Figure 6-Elements at Starboard side of Gondola

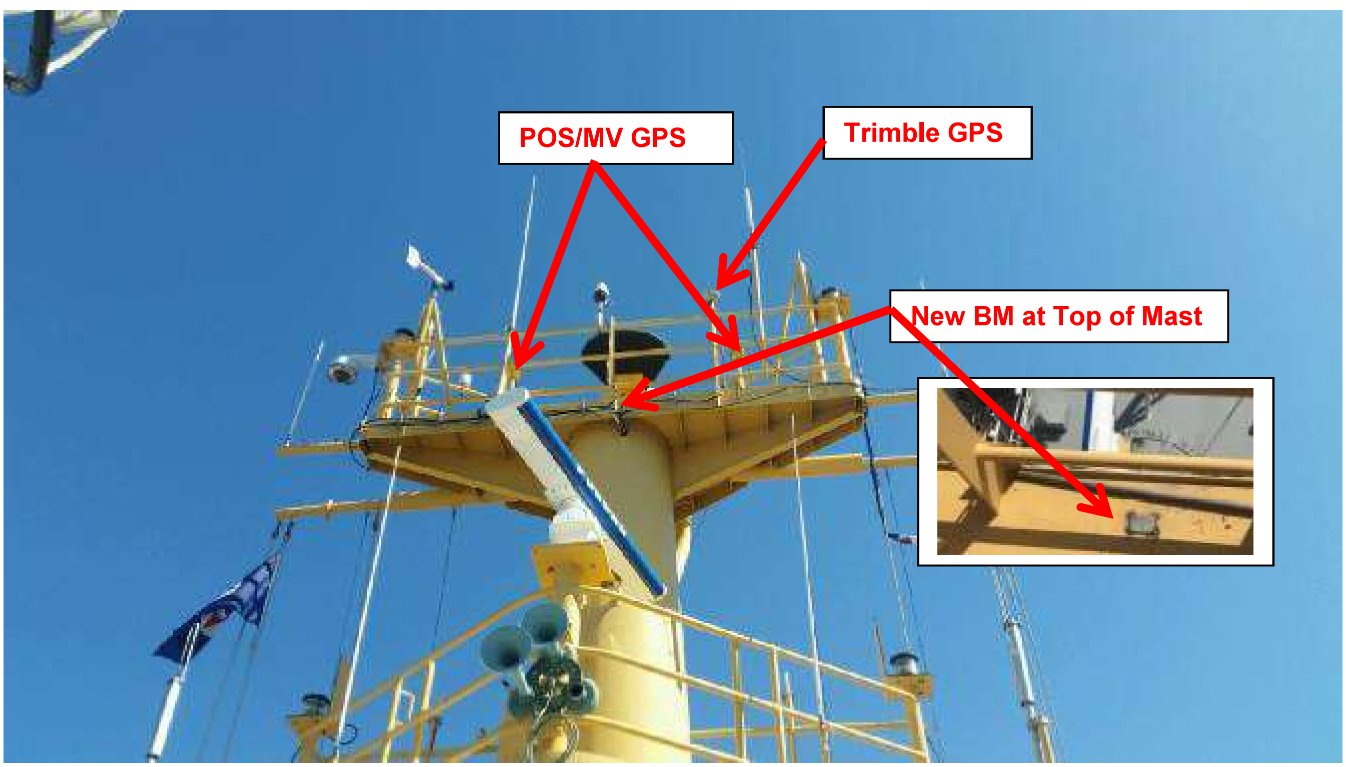



Figure 7- Mast Elements

Figure 8-GPS Antenna Elevations at bottom of Mount


Figure 9 – Scientific Store Room

BM#1


BM#2

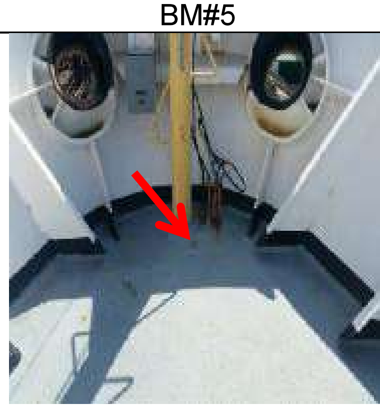

BM#3


BM#4


BM#5


BM#6


BM#7


BM#12


BM#13


BM#14


New Aft BM


New BM Top Pilot House

Figure 10 – Bench Marks

## Measurement Precision and Uncertainty

Uncertainties are reported to be:

Point to Point, any element or target within the vessel survey to another element or feature in the survey

$X, Y, \& Z \leq 1.5$ mm

Region to Region, i.e., GPS antenna to EM710 RX/TX features:

$X \leq 2.0$ mm
$Y \leq 2.0$ mm
$Z \leq 2.0$ mm

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision of the survey is analyzed to be:

Azimuth, Pitch, Roll: ≤ 00° 00' 30"

## PROJECT DATA

The required data is summarized in tabular form on the following pages. The units of measure for reporting are indicated on each table.

Table 1 reports the X, Y and Z, values for specified elements in units of meters and in the vessel coordinate system (Kongsberg System)

Table 2 reports the X, Y and Z, values for specified bench marks in units of meters and in the vessel coordinate system (Kongsberg system).

Table 3 reports the Azimuth, Pitch and Roll of specified elements in Kongsberg system.

Table 4 reports the summarized data for the draft mark survey and is presented with Feet as the unit of measure to correlate with the specific draft mark number. Draft mark elevations are reported above the best-fit keel as surveyed. The gondola projection is not reflected by any set of draft marks and projects 1.4 feet below the keel.

Appendix 1 is a copy of tables with the data presented with respect to the 1st coordinate system requested by NOAA EM710Tx Transducer Center as Origin and plane defining Pitch & Roll with azimuth clocked to X axis of transducer.

Appendix 2 is a copy of tables with the data presented with respect to the 2$^{nd}$ coordinate system requested by NOAA; IMU Center as Origin and plane IMU defining Pitch & Roll with azimuth clocked to X axis of IMU.

Appendix 3 is a copy of tables with the data presented with respect to the 3$^{rd}$ coordinate system requested by NOAA; ORU Center as Origin and ORU plane defining Pitch & Roll with azimuth clocked to X axis of ORU.

| [3] TABLE 1-ELEMENT COORDINATES SHIP SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| IMU (XYZ) | 0.000 | 0.000 | 0.000 |
| ORU (ORIGIN) | -0.843 | -0.012 | -0.132 |
| 710TX (XYZ) | -0.488 | 2.333 | 5.010 |
| 710RX (XYZ) | -1.760 | 2.434 | 5.008 |
| 2040RX (XYZ) | -2.851 | 2.397 | 5.012 |
| 2040TX (XYZ) | -2.953 | 2.092 | 5.027 |
| [1] BUBBLER ORIFICE Z | -2.989 | 2.926 | 3.917 |
| 24/200 (XYZ) | -1.264 | 0.305 | 4.439 |
| 200KHZ_1 (XYZ) | -1.911 | 0.573 | 4.887 |
| 12KHZ_1 (XYZ) | -2.431 | 0.570 | 4.887 |
| 38KHZ (XYZ) | -3.084 | 0.567 | 4.890 |
| 3.5KHZ (XYZ) | -1.873 | 6.032 | 4.398 |
| SEC INTAKE (XYZ) | -3.106 | 7.784 | 4.187 |
| SRD500 (XYZ) | -3.066 | 5.183 | 4.594 |
| VALVE PORT (XYZ) | -2.950 | 3.250 | 4.564 |
| BUBBLER INTAKE (XYZ) | -3.090 | 2.733 | 5.010 |
| 50KHZ (XYZ) | -2.611 | 2.881 | 5.012 |
| PRIMARY INTAKE (XYZ) | -2.487 | 3.013 | 5.010 |
| 200KHZ_2 (XYZ) | -2.344 | 2.882 | 5.012 |
| 12KHZ_2 (XYZ) | -1.272 | 4.555 | 4.438 |
| [2] TRIMBLE GPS | -9.040 | 1.575 | -22.214 |
| [2] POS MV PORT | -9.924 | 1.373 | -22.344 |
| [2] POS MV STBD | -9.913 | 3.583 | -22.335 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) Kongsberg System Ships Orthogonal system on TDC IMU

| TABLE 2- BENCH MARKS SHIP SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.027 | -0.567 | 0.287 |
| SCI STORE INTR #2 | -1.132 | -0.577 | 0.291 |
| SCI STORE AFT #3 | -3.294 | -0.589 | 0.289 |
| FWD KEEL #4 | -2.787 | 1.515 | 4.555 |
| AFT KEEL #5 | -16.152 | 1.51 | 4.557 |
| MAIN PASS #6 | -6.435 | 3.337 | -2.517 |
| DC PASS #7 | -16.141 | 3.287 | -2.51 |
| BOW FWD #12 | 21.026 | 2.535 | -5.183 |
| BOW MID #13 | 17.187 | 2.516 | -5.175 |
| BOW AFT#14 | 14.643 | 2.512 | -5.192 |
| PILOT HOUSE (NEW) | -7.568 | 5.304 | -12.92 |
| TOP MAST (NEW) | -9.151 | 2.942 | -20.999 |
| STBD AFT END (New) | -39.506 | 7.544 | -3.079 |

| TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| SHIP SYSTEM | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| IMU | 0.64167 | STBD | 0.07198 | BOW DOWN | 0.24375 | STBD DOWN |
| ORU | 0.04400 | PORT | 0.08500 | BOW DOWN | 0.07779 | STBD DOWN |
| EM710 TX | 0.05539 | PORT | 0.01315 | BOW UP | 0.00927 | STBD UP |
| EM710RX | 0.21797 | STBD | 0.09935 | BOW UP | 0.06457 | STBD DOWN |
| EM2040TX | 0.1466 | STBD | 0.19035 | BOW UP | 0.08625 | STBD UP |
| EM2040RX | 0.13963 | STBD | 0.20005 | BOW UP | 0.17817 | STBD UP |

| TABLE 4 - DRAFT MARKS (elev above keel, feet) | | | | | | | |
|---|---|---|---|---|---|---|---|
| PORT | | | | STARBOARD | | | |
| DRAFT MARK | ELEVATION AS SURVEYED | | | DRAFT MARK | ELEVATION AS SURVEYED | | |
| | FWD | MID | AFT | | FWD | MID | AFT |
| 12 | - | - | - | 12 | - | 11.9 | - |
| 13 | 12.9 | - | - | 13 | 12.9 | - | - |
| 14 | 13.9 | 14.0 | - | 14 | 13.9 | 13.9 | - |
| 15 | 15.0 | 15.0 | 15.1 | 15 | 15.0 | 14.9 | 15.1 |
| 16 | 16.0 | 16.0 | 16.1 | 16 | 16.0 | 15.9 | 16.0 |
| 17 | 16.9 | 17.0 | 17.1 | 17 | 16.9 | 16.9 | 17.1 |

# Certificate of Calibration

Item No. / Model: NET 1200

Manufacturer: SOKKIA

Serial No.: 110554 Certificate Number: 60997

This certifies that the above instrument has been inspected and calibrated by the Sokkia Corporation Service Department. This inspection was performed using the procedures set forth in the NET SERIES INSTRUMENT CALIBRATION AND CERTIFICATION MANUAL (August 18, 2005 Rev. 8). At the time of completion of this service, Sokkia Corporation certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. The certification is effective for a 12 month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (N.I.S.T) via Multual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures.

The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 (and, as a result ISO 9001-1994 or ISO 9002-1994)

This certificate shall not be reproduced except in full, without the written approval of Sokkia Corporation

Customer Name: IMTEC GROUP, Ltd

Customer Address: 19004 E. RINGO CIR.

Customer City/State/Zip: INDEPENDENCE, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 11/17/2015 Date Recalibration Due: 11/17/2016

Signed: Ale Erhin Date: 11/17/2015

| Yes | No | |
|---|---|---|
| | X | Is this a new instrument? |

Answer the following questions only if the above answer is "No".

| Yes | No | |
|---|---|---|
| | X | Is this the first NIST calibration we have performed on this instrument? |
| X | | Were the calibration seals intact when the instrument was received? |
| | X | Were the initial collimation inspection results within tolerance? |
| | X | Were the initial EDM inspection results within tolerance? |
| | X | Was the instrument damaged/defective and unable to have an initial inspection? |
| | X | Corrective action recommended? |

* See page 2 for a list of primary standards

Page 1 of 2

## Appendix 1 – NOAA Requested System wrt 710TX

| (3) A1 TABLE 1-ELEMENT COORDINATES 710TX SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| IMU (XYZ) | 0.491 | -2.332 | -5.010 |
| ORU (ORIGIN) | -0.351 | -2.345 | -5.143 |
| 710TX (XYZ) | 0.000 | 0.000 | 0.000 |
| 710RX (XYZ) | -1.273 | 0.099 | -0.002 |
| 2040RX (XYZ) | -2.363 | 0.061 | 0.001 |
| 2040TX (XYZ) | -2.465 | -0.244 | 0.016 |
| (1)BUBBLER ORIFICE Z | -2.501 | 0.590 | -1.094 |
| 24/200 (XYZ) | -0.774 | -2.029 | -0.571 |
| 200KHZ_1 (XYZ) | -1.421 | -1.762 | -0.124 |
| 12KHZ_1 (XYZ) | -1.942 | -1.765 | -0.123 |
| 38KHZ (XYZ) | -2.594 | -1.769 | -0.121 |
| 3.5KHZ (XYZ) | -1.389 | 3.698 | -0.612 |
| SEC INTAKE (XYZ) | -2.623 | 5.448 | -0.823 |
| SRD500 (XYZ) | -2.581 | 2.847 | -0.417 |
| VALVE PORT (XYZ) | -2.463 | 0.914 | -0.447 |
| BUBBLER INTAKE (XYZ) | -2.603 | 0.397 | -0.001 |
| 50KHZ (XYZ) | -2.124 | 0.545 | 0.002 |
| PRIMARY INTAKE (XYZ) | -2.000 | 0.678 | 0.000 |
| 200KHZ_2 (XYZ) | -1.857 | 0.546 | 0.002 |
| 12KHZ_2 (XYZ) | -0.786 | 2.221 | -0.572 |
| (2)TRIMBLE GPS | -8.545 | -0.762 | -27.226 |
| (2)POS MV PORT | -9.429 | -0.965 | -27.357 |
| (2)POS MV STBD | -9.420 | 1.245 | -27.347 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 1 Orthogonal system on 710TX

| A1 TABLE 2- BENCH MARKS 710TX SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.519 | -2.898 | -4.723 |
| SCI STORE INTR #2 | -0.64 | -2.911 | -4.72 |
| SCI STORE AFT #3 | -2.803 | -2.924 | -4.722 |
| FWD KEEL #4 | -2.299 | -0.82 | -0.456 |
| AFT KEEL #5 | -15.663 | -0.838 | -0.457 |
| MAIN PASS #6 | -5.946 | 1 | -7.528 |
| DC PASS #7 | -15.652 | 0.94 | -7.523 |
| BOW FWD #12 | 21.516 | 0.224 | -10.189 |
| BOW MID #13 | 17.677 | 0.201 | -10.181 |
| BOW AFT#14 | 15.133 | 0.195 | -10.198 |
| PILOT HOUSE (NEW) | -7.079 | 2.967 | -17.931 |
| TOP MAST (NEW) | -8.658 | 0.604 | -26.011 |
| STBD AFT END (New) | -39.022 | 5.174 | -8.097 |

| A1 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS 710 TX SYSTEM (decimal dgrees) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.69705 | STBD | 0.08490 | BOW DOWN | 0.25310 | STBD DOWN |
| ORU | 0.01138 | STBD | 0.09813 | BOW DOWN | 0.08710 | STBD DOWN |
| EM710 TX | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| EM710RX | 0.27337 | STBD | 0.08627 | BOW UP | 0.07377 | STBD DOWN |
| EM2040TX | 0.20202 | STBD | 0.17713 | BOW UP | 0.07714 | STBD UP |
| EM2040RX | 0.19498 | STBD | 0.18675 | BOW UP | 0.16907 | STBD UP |

## Appendix 2 – NOAA Requested System wrt IMU

| (3) A2 TABLE 1-ELEMENT COORDINATES IMU SYSTEM (m) | | | |
|---|---|---|---|
| ELEMENT | X | Y | Z |
| (4)IMU (XYZ) | 0 | 0 | 0 |
| ORU (ORIGIN) | -0.843 | -0.003 | -0.131 |
| 710TX (XYZ) | -0.455 | 2.36 | 5.001 |
| 710RX (XYZ) | -1.727 | 2.474 | 5 |
| 2040RX (XYZ) | -2.818 | 2.45 | 5.005 |
| 2040TX (XYZ) | -2.923 | 2.146 | 5.022 |
| (1)BUBBLER ORIFICE Z | -2.951 | 2.975 | 3.908 |
| 24/200 (XYZ) | -1.255 | 0.338 | 4.44 |
| 200KHZ_1 (XYZ) | -1.898 | 0.615 | 4.887 |
| 12KHZ_1 (XYZ) | -2.418 | 0.618 | 4.888 |
| 38KHZ (XYZ) | -3.071 | 0.623 | 4.892 |
| 3.5KHZ (XYZ) | -1.8 | 6.071 | 4.375 |
| SEC INTAKE (XYZ) | -3.013 | 7.836 | 4.157 |
| SRD500 (XYZ) | -3.002 | 5.237 | 4.575 |
| VALVE PORT (XYZ) | -2.908 | 3.302 | 4.554 |
| BUBBLER INTAKE (XYZ) | -3.053 | 2.789 | 5.002 |
| 50KHZ (XYZ) | -2.572 | 2.931 | 5.003 |
| PRIMARY INTAKE (XYZ) | -2.447 | 3.062 | 5 |
| 200KHZ_2 (XYZ) | -2.305 | 2.929 | 5.003 |
| 12KHZ_2 (XYZ) | -1.215 | 4.588 | 4.42 |
| (2)TRIMBLE GPS | -9.051 | 1.582 | -22.209 |
| (2)POS MV PORT | -9.937 | 1.389 | -22.338 |
| (2)POS MV STBD | -9.901 | 3.599 | -22.337 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 2 Orthogonal system on IMU
(4)TDC IMU is 4.6 meters above Keel

| A2 TABLE 2- BENCH MARKS IMU SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.021 | -0.577 | 0.289 |
| SCI STORE INTR #2 | -1.138 | -0.563 | 0.294 |
| SCI STORE AFT #3 | -3.300 | -0.550 | 0.296 |
| FWD KEEL #4 | -2.764 | 1.566 | 4.552 |
| AFT KEEL #5 | -16.128 | 1.710 | 4.571 |
| MAIN PASS #6 | -6.400 | 3.399 | -2.523 |
| DC PASS #7 | -16.106 | 3.457 | -2.503 |
| BOW FWD #12 | 21.046 | 2.277 | -5.221 |
| BOW MID #13 | 17.207 | 2.301 | -5.207 |
| BOW AFT#14 | 14.664 | 2.326 | -5.221 |
| PILOT HOUSE (NEW) | -7.525 | 5.334 | -12.932 |
| TOP MAST (NEW) | -9.145 | 2.955 | -21.000 |
| STBD AFT END (New) | -39.423 | 7.973 | -3.061 |

| A2 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees IMU System) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| ORU | 0.68556 | PORT | 0.01122 | BOW DOWN | 0.16615 | STBD UP |
| EM710 TX | 0.69738 | PORT | 0.08796 | BOW UP | 0.25206 | STBD UP |
| EM710RX | 0.42371 | PORT | 0.17333 | BOW UP | 0.17725 | STBD UP |
| EM2040TX | 0.49611 | PORT | 0.26602 | BOW UP | 0.32704 | STBD UP |
| EM2040RX | 0.50177 | PORT | 0.27675 | BOW UP | 0.41885 | STBD UP |

## Appendix 3 – NOAA Requested Coordinates wrt ORU

| (3) A3 TABLE 1-ELEMENT COORDINATES ORU SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| (4)IMU (XYZ) | 0.843 | 0.013 | 0.131 |
| ORU (ORIGIN) | 0.000 | 0.000 | 0.000 |
| 710TX (XYZ) | 0.361 | 2.353 | 5.139 |
| 710RX (XYZ) | -0.912 | 2.452 | 5.139 |
| 2040RX (XYZ) | -2.003 | 2.414 | 5.144 |
| 2040TX (XYZ) | -2.105 | 2.109 | 5.160 |
| (1)BUBBLER ORIFICE Z | -2.142 | 2.941 | 4.048 |
| 24/200 (XYZ) | -0.415 | 0.322 | 4.572 |
| 200KHZ_1 (XYZ) | -1.061 | 0.591 | 5.020 |
| 12KHZ_1 (XYZ) | -1.582 | 0.587 | 5.021 |
| 38KHZ (XYZ) | -2.234 | 0.584 | 5.025 |
| 3.5KHZ (XYZ) | -1.029 | 6.049 | 4.524 |
| SEC INTAKE (XYZ) | -2.263 | 7.800 | 4.312 |
| SRD500 (XYZ) | -2.221 | 5.200 | 4.722 |
| VALVE PORT (XYZ) | -2.103 | 3.266 | 4.695 |
| BUBBLER INTAKE (XYZ) | -2.242 | 2.750 | 5.142 |
| 50KHZ (XYZ) | -1.763 | 2.898 | 5.143 |
| PRIMARY INTAKE (XYZ) | -1.639 | 3.031 | 5.141 |
| 200KHZ_2 (XYZ) | -1.496 | 2.899 | 5.143 |
| 12KHZ_2 (XYZ) | -0.426 | 4.573 | 4.565 |
| (2)TRIMBLE GPS | -8.231 | 1.550 | -22.071 |
| (2)POS MV PORT | -9.115 | 1.348 | -22.201 |
| (2)POS MV STBD | -9.106 | 3.558 | -22.194 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 3 Orthogonal system on ORU
(4)TDC ORU is 4.7 meters above Keel

| A3 TABLE 2- BENCH MARKS ORU SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.871 | -0.553 | 0.418 |
| SCI STORE INTR #2 | -0.288 | -0.565 | 0.424 |
| SCI STORE AFT #3 | -2.451 | -0.578 | 0.426 |
| FWD KEEL #4 | -1.939 | 1.532 | 4.688 |
| AFT KEEL #5 | -15.304 | 1.517 | 4.710 |
| MAIN PASS #6 | -5.598 | 3.342 | -2.381 |
| DC PASS #7 | -15.304 | 3.284 | -2.359 |
| BOW FWD #12 | 21.859 | 2.556 | -5.087 |
| BOW MID #13 | 18.020 | 2.535 | -5.072 |
| BOW AFT#14 | 15.476 | 2.529 | -5.086 |
| PILOT HOUSE (NEW) | -6.749 | 5.294 | -12.784 |
| TOP MAST (NEW) | -8.342 | 2.919 | -20.858 |
| STBD AFT END (New) | -38.674 | 7.522 | -2.900 |

| A3 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees ORU System) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.68529 | STBD | 0.01321 | BOW UP | 0.16601 | STBD DOWN |
| ORU | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| EM710 TX | 0.01276 | PORT | 0.09815 | BOW UP | 0.08708 | STBD UP |
| EM710RX | 0.26191 | STBD | 0.18441 | BOW UP | 0.01330 | STBD UP |
| EM2040TX | 0.18694 | STBD | 0.27532 | BOW UP | 0.16419 | STBD UP |
| EM2040RX | 0.18391 | STBD | 0.28496 | BOW UP | 0.25613 | STBD UP |
| 24/200 kHz | - | - | 0.47762 | BOW UP | 0.02678 | STBD DOWN |
| 12kHz-2 | - | - | 0.36558 | BOW UP | 0.23158 | STBD UP |
| 12kHz-1 | - | - | 0.23913 | BOW UP | 0.09000 | STBD UP |
| 200kHz-1 | - | - | 0.13427 | BOW UP | 0.46860 | STBD UP |
| 200kHz-2 | - | - | 0.08863 | BOW UP | 0.32335 | STBD UP |
| 38kHz | - | - | 0.32417 | BOW UP | 0.01594 | STBD DOWN |
| 50kHz | - | - | 0.34673 | BOW UP | 0.43530 | STBD UP |
| SRD500 | - | - | 0.54483 | BOW UP | 0.71415 | STBD DOWN |
| 3.5 kHz | - | - | 0.17175 | BOW UP | 0.04851 | STBD DOWN |
| ADCP(1) | - | - | - | - | - | - |

(1) ADCP not installed at time of survey

# Appendix 4:

# Position and attitude calibration

Updated: 6/5/2018

## Appendix 4.1: S222 Position and attitude calibration

# S222 position and attitude calibration

The Applanix POS MV configuration was not altered in any way between the end of the 2017 field season and the beginning of the 2018 field season. As such, antenna vector values from 2017 were used for the 2018 field season.

# POS/MV Calibration Report

**Field Unit: Thomas Jefferson**

## SYSTEM INFORMATION

**Vessel:** S222

**Date:** 7/12/2017 **Dn:** 193

**Personnel:** Marcus,Hiteshew,Doroba

**PCS Serial #** 6497

**IP Address:** 129.100.1.231

**POS controller Version (Use Menu Help > About)** 8.6

**POS Version (Use Menu View > Statistics)** V5

**GPS Receivers**

**Primary Receiver** BD982 S/N 5409C86558

**Secondary Receiver**

## CALIBRATION AREA

**Location:** E of Cape Henry

**Approximate Position:**

| | D | M | S |
|---|---|---|---|
| **Lat** | 36 | 54 | 13 |
| **Lon** | 75 | 50 | 35 |

**DGPS Beacon Station:** MarineStar

**Frequency:**

## Satellite Constellation

(Use View> GPS Data)

**Primary GPS (Port Antenna)**

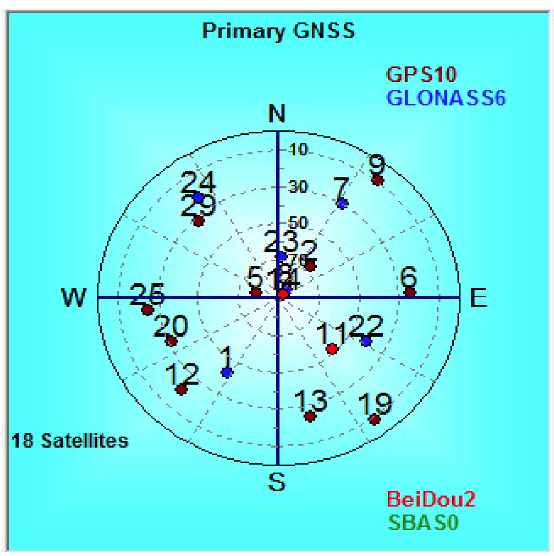
**HDOP:** 0.676

**VDOP:** 1.062

**Sattelites in Use:** 10

**PDOP** 2.000 (Use View> GAMS Solution)

N




**Note**:

## POS/MV CONFIGURATION

### Settings

**Gams Parameter Setup** (Use Settings > Installation > GAMS Intallation)

User Entries, Pre-Calibration

| | |
|---|---|
| **2.21** | Two Antenna Separation (m) |
| **0.50** | Heading Calibration Threshold |
| **0** | Heading Correction |

Baseline Vector

| | |
|---|---|
| **0.019** | X Component (m) |
| **2.208** | YComponent (m) |
| **-0.009** | Z Component (m) |

**Configuration Notes:**

## POS/MV CALIBRATION

### Calibration Procedure:

(Refer to POS MV V3 Installation and Operation Guide, 4-25)

Start time: 2341 UTC

End time: 0005

Heading accuracy achieved for calibration: 0.486

### Calibration Results:

**Gams Parameter Setup** (Use Settings > Installation > GAMS Intallation)

POS/MV Post-Calibration Values

| | |
|---|---|
| **2.21** | Two Antenna Separation (m) |
| **0.500** | Heading Calibration Threshold |
| **0** | Heading Correction |

Baseline Vector

| | |
|---|---|
| **0.019** | X Component (m) |
| **2.208** | YComponent (m) |
| **-0.009** | Z Component (m) |

GAMS Status Online? Yes

Save Settings? Yes

**Calibration Notes:**

**Save POS Settings on PC** (Use File > Store POS Settings on PC)

File Name: PosConfig_13Jul2017.nvm

## GENERAL GUIDANCE

**The POS/MV uses a Right-Hand Orthogonal Reference System**

The right-hand orthogonal system defines the following:

- The x-axis is in the fore-aft direction in the appropriate reference frame.
- The y-axis is perpendicular to the x-axis and points towards the right (starboard) side in the appropriate reference frame.
- The z-axis points downwards in the appropriate reference frame.

**The POS/MV uses a Tate-Bryant Rotation Sequence**

Apply the rotation in the following order to bring the two frames of reference into complete alignment:

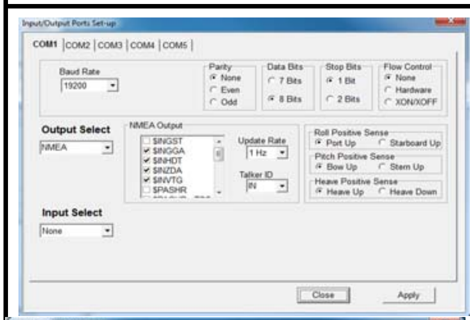
a) Heading rotation - apply a right-hand screw rotation θz about the z-axis to align one frame with the other.

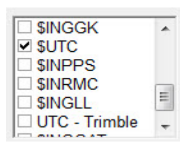
b) Pitch rotation - apply a right-hand screw rotation θy about the once-rotated y-axis to align one frame with the other.

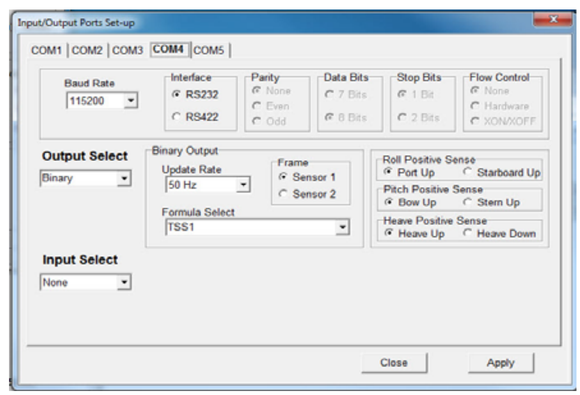
c) Roll rotation - apply a right-hand screw rotation θx about the twice-rotated x-axis to align one frame with the other.

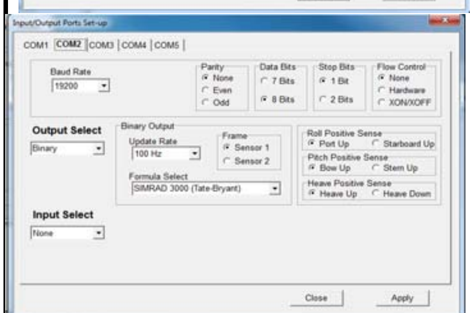
## SETTINGS (insert screen grabs)

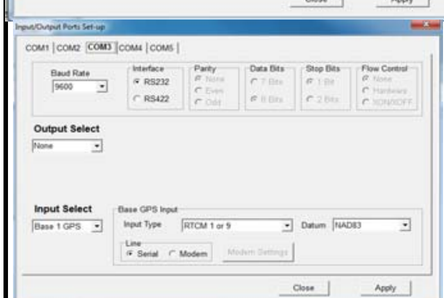
**Input/Output Ports** (Use Settings > Input/Output Ports)

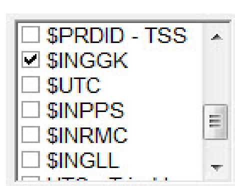


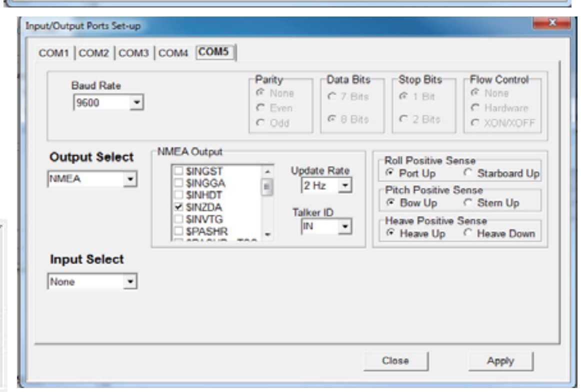


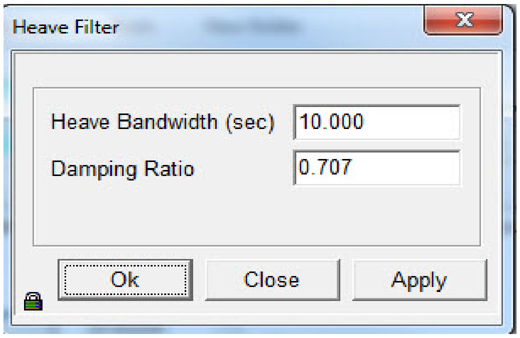




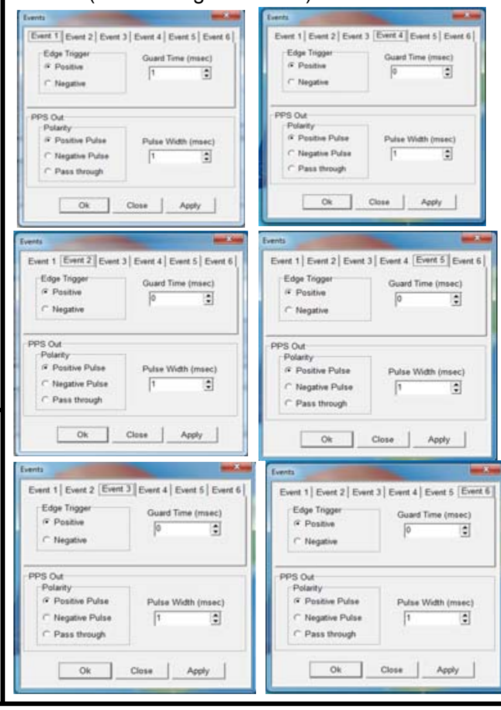




NOTE:

**Heave Filter** (Use Settings > Heave)



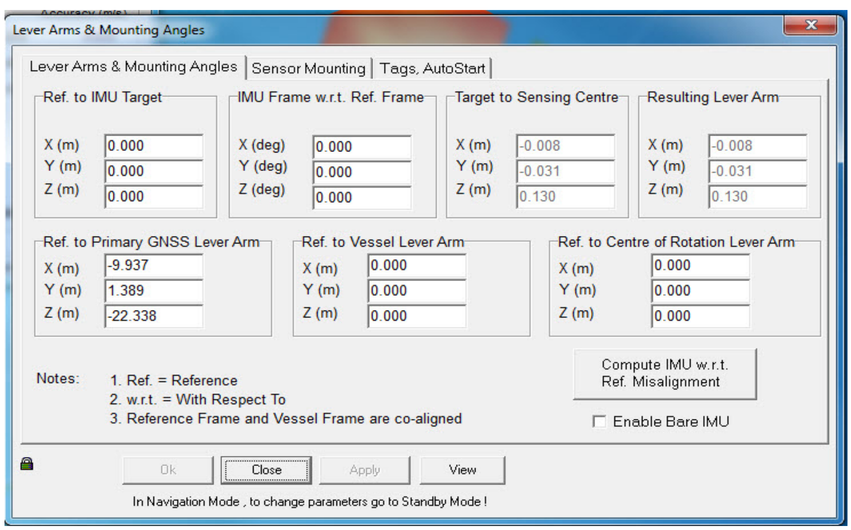

**Events** (Use Settings > Events)



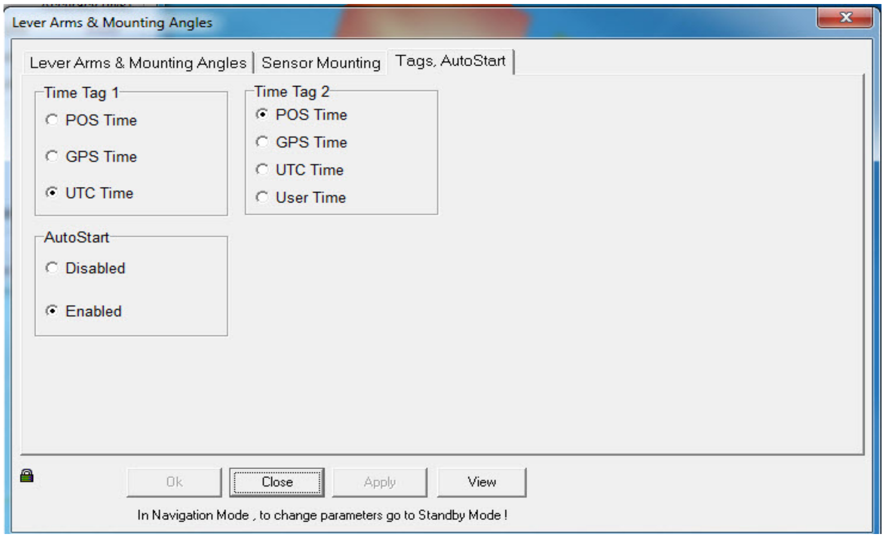

**Time Sync** (Use Settings > Time Sync)

NOT ON THE VERSION 4

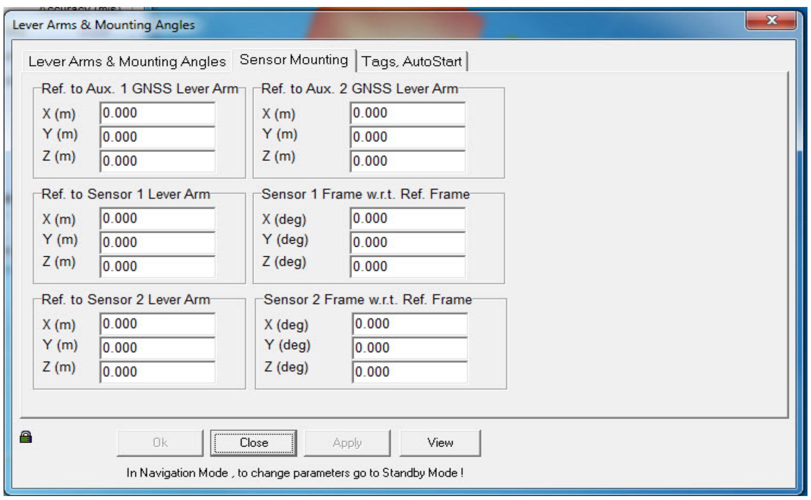
## Installation (Use Settings > Installation)



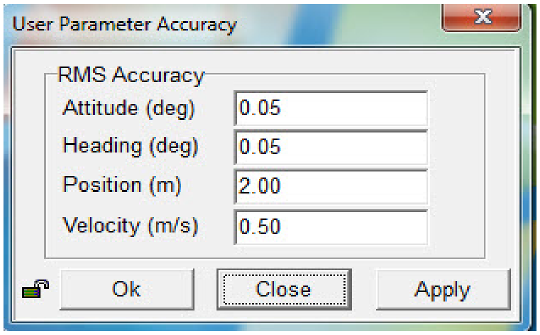
**Tags, Multipath and Auto Start** (Use Settings > Installation > Tags, Multipath and Auto Start)




**Sensor Mounting** (Use Settings > Installation > Sensor Mounting)



**User Parameter Accuracy** (Use Settings > Installation > User Accuracy)

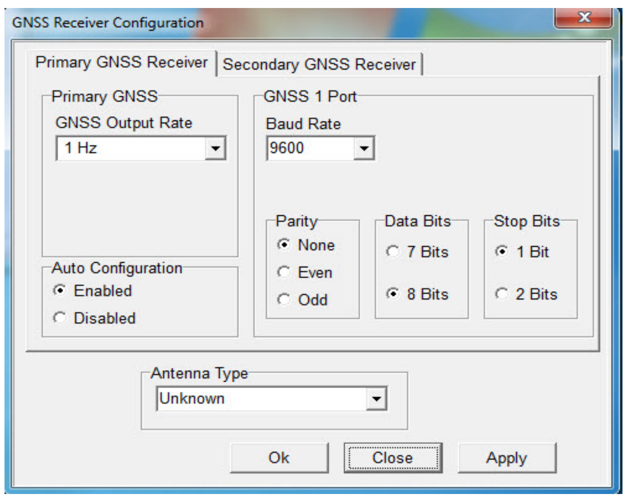



**Frame Control** (Use Tools > Config)

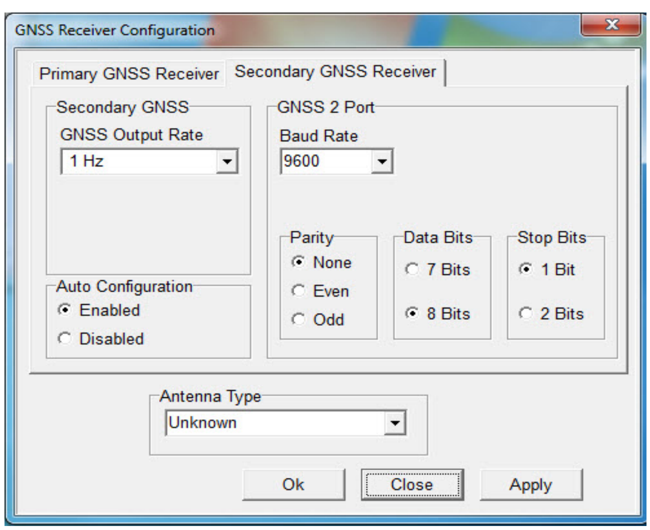
NOT ON THE VERSION 4

## GPS Receiver Configuration (Use Settings> Installation> GPS Receiver Configuration)

**Primary GPS Receiver**




**Secondary GPS Receiver**



# Appendix 4.2: 2903 Position and attitude calibration

# Applanix GAMS calibration report for HSL 2903

Date:

2018-06-05

Processor:

LT Charles Wisotzkey, NOAA

Method:

Post-processed GAMS Calibration

Procedure:

A GAMS calibration was conducted in the field during the acceptance for the EM2040 on 22 May 2018. A GAMS calibration report was not specifically generated for that calibration.

A post-processed GAMS calibration procedure was used to confirm A-B baseline vector values determined during the acceptance tests. All raw POS data logged on 22 May 2018 and 23 May 2018 was processed in Applanix POSPac 8.2.1, however, the values below were derived from the logged data for the period when GAMS calibration was conducted.

The GAMS Baseline Vector was set to an ‘Unk.’ standard deviation value:

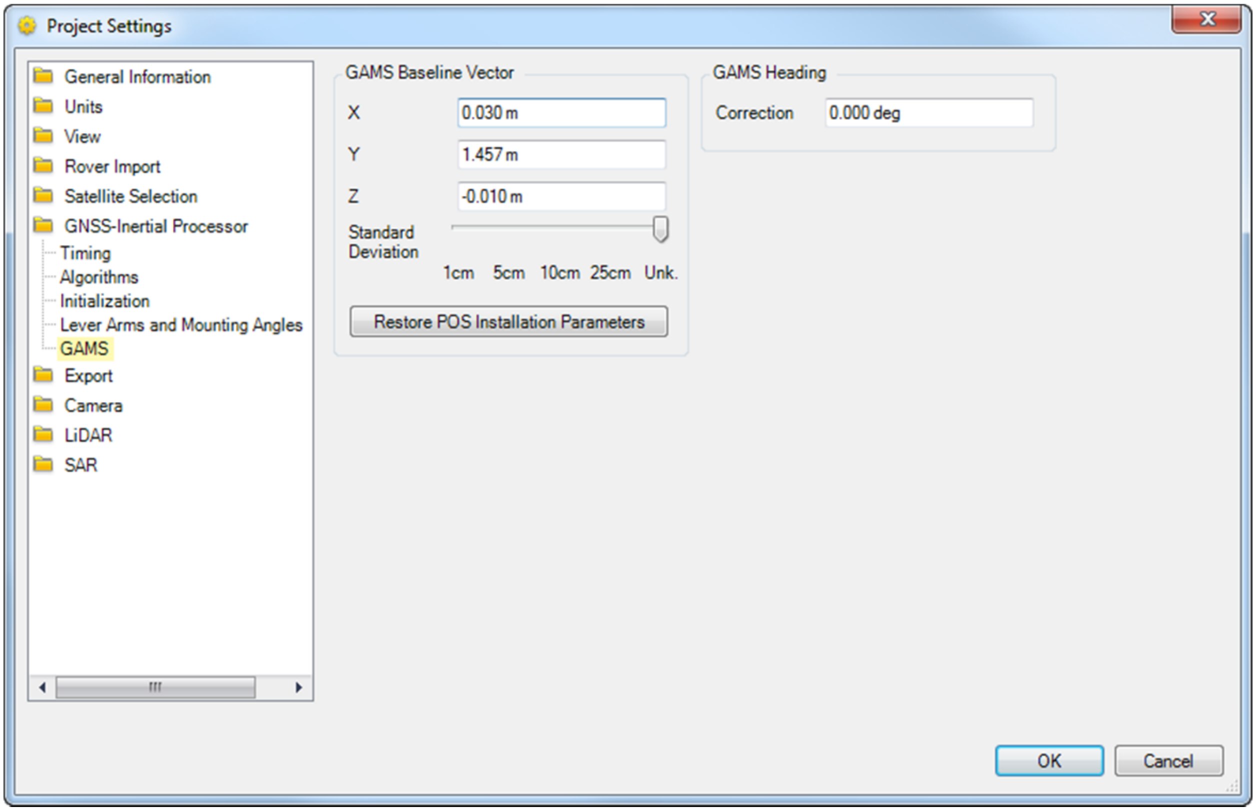



Figure 01: Project Settings / GNSS-Inertial Processor / GAMS

The POS data was then post-processed using the ‘Primary Marinestar Nav’ GNSS-Inertial Processor processing mode:

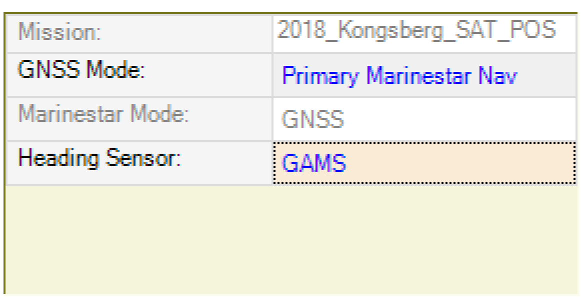



Figure 02: GNSS-Inertial Processor processing mode

The resultant Calibrated Installation Parameters values were then examined in the POSPac MMS Display Plots tool:

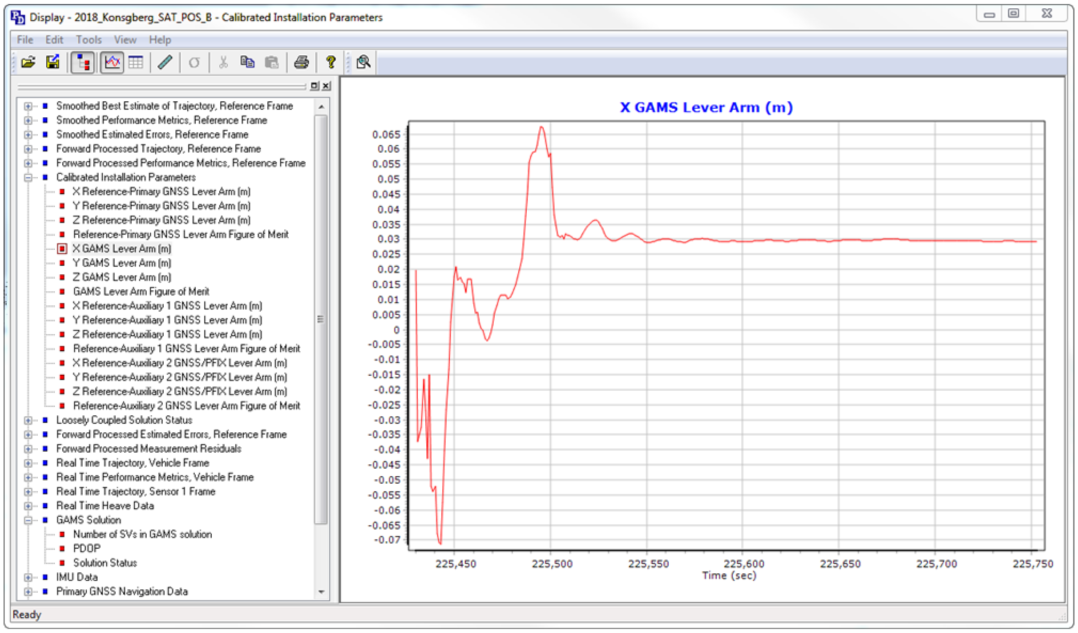



Figure 03: Calibrated Installation Parameters / X GAMS Lever Arm (m)

Settled X Lever Arm Value:  ~ -0.009 m

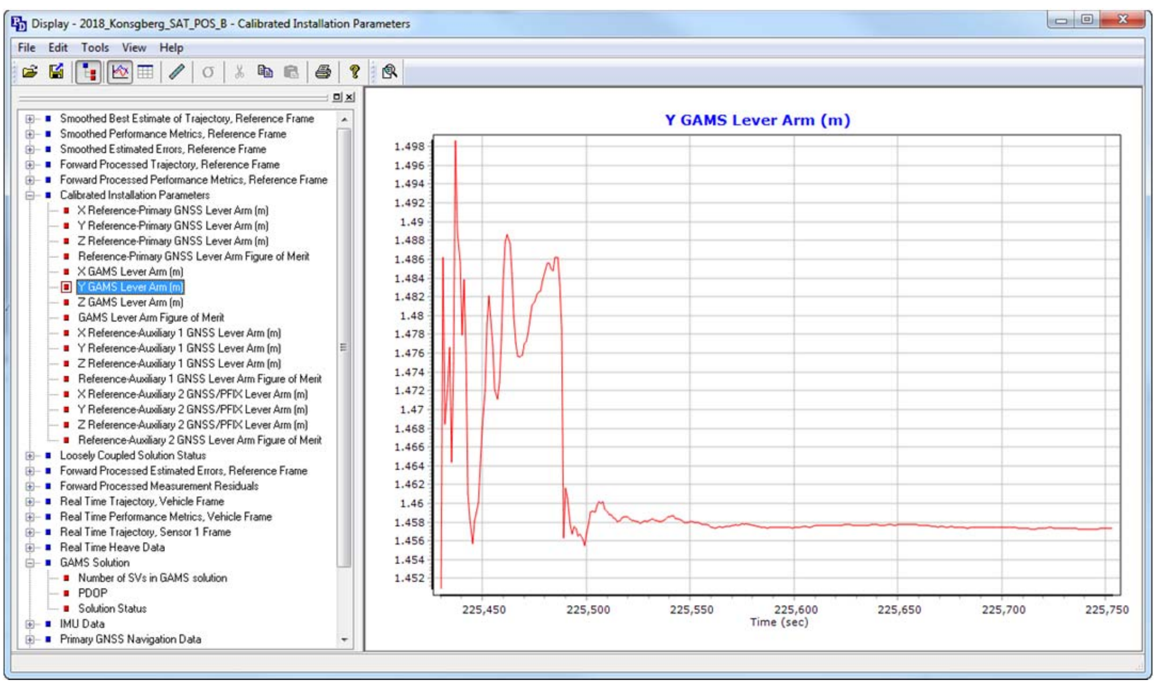



Figure 04: Calibrated Installation Parameters / Y GAMS Lever Arm (m)

Settled Y Lever Arm Value: ~ +1.459 m

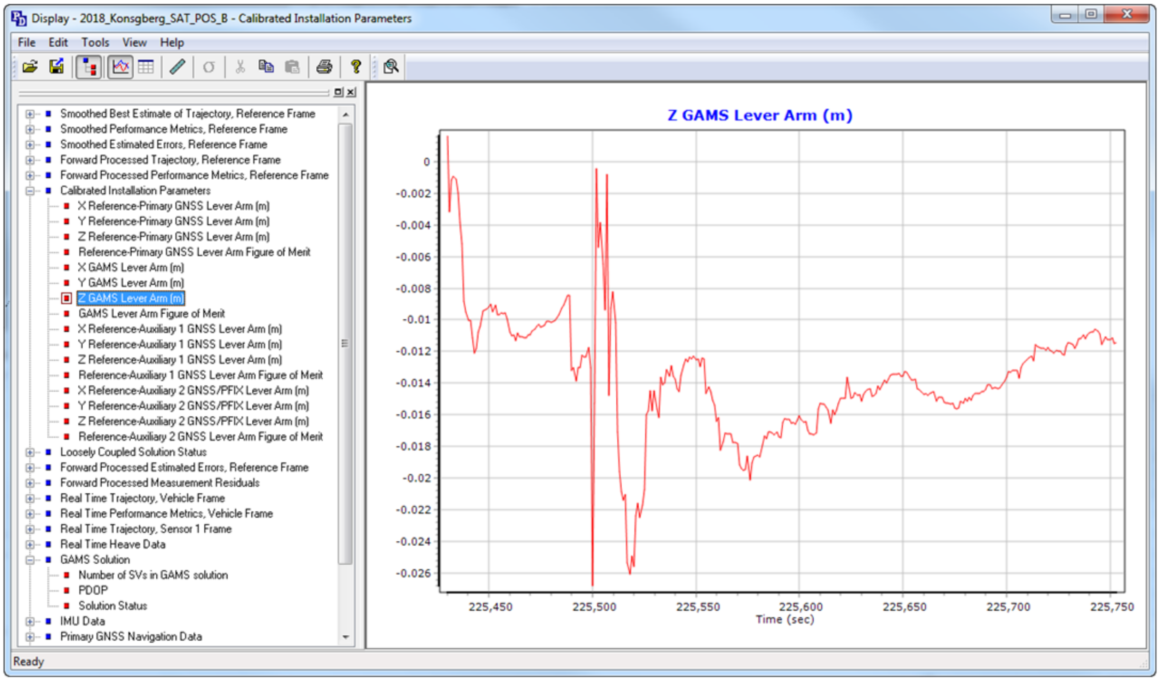



Figure 05: Calibrated Installation Parameters / Z GAMS Lever Arm (m)

Settled Z Lever Arm Value: ~ -0.0105 m

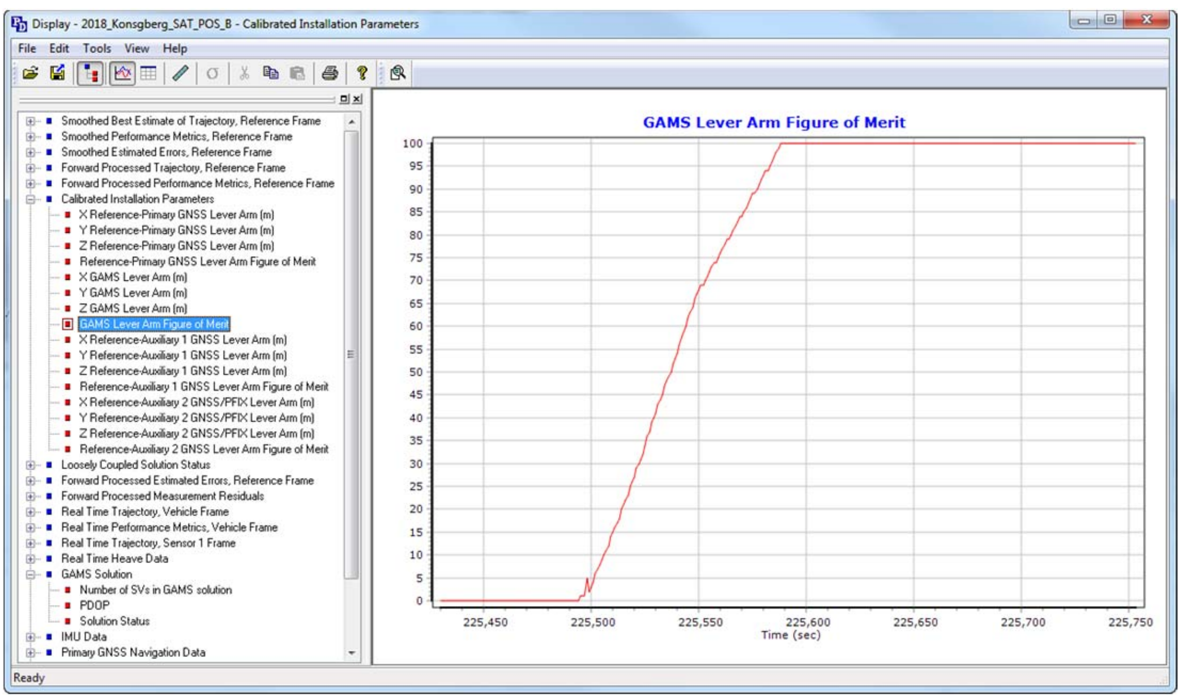



Figure 06: Calibrated Installation Parameters / GAMS Lever Arm Figure of Merit

# Appendix 4.3: 2904 Position and attitude calibration

## Applanix GAMS calibration report for HSL 2904

NOAA HSL 2904 with new Kongsberg EM2040 MBES systems had not completed sonar acceptance testing or confidence checks at the time of submission of this report.

A GAMS calibration had not been conducted for HSL 2904 at the time of submission of this report.

HSL 2904 has not been used for any survey operations since installation of the new sonar systems.

This report will be updated upon completion of sonar acceptance and confidence checks.

# Appendix 5:

# Echosounder confidence checks

Updated: 6/5/2018

Appendix 5.1: S222 Echosounder Confidence Check

# S222 Echosounder Confidence Check

Patch test values from the initial sonar acceptance testing for the EM710 and EM2040 sonars in 2016 were used for the 2018 field season. These values were confirmed through and analysis of reference surface comparisons.

See the appendix titled ‘NOAA SHIP THOMAS JEFFERSON EM710 AND EM2040 ACCEPTANCE TESTING’ for further information.

**NOAA Ship S222 2018 75m Range Scale Sidescan Calibration**
**Side Scan run on DN112. MBES not run.**

**2018 HSRR**
**S222 75m Range Scale**
**Side Scan Certification**

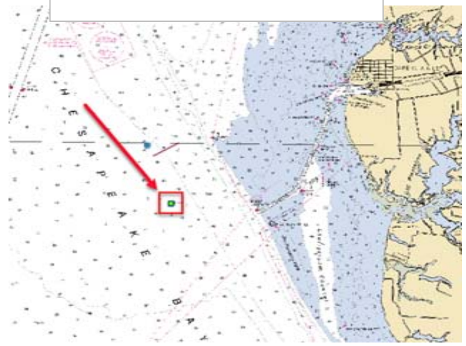


Figure 1: 2018 HSRR 75m Range Scale Side Scan Cert site off Cape Henry

**MBES Position of Contact**

| | Lat | Long |
|---|---|---|
| | 37.2337765 | -76.0775678 |

| SSS Contacts | | | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 37.2337920 | -76.0775380 | 0 | 1.73 | 2.64 | 3.15 | 2.64 | 1.727 | 3.15 |
| 2 | 37.233794 | -76.077579 | 179 | 1.95 | -0.99 | 2.19 | 0.96 | -1.967 | 2.19 |
| 3 | 37.233799 | -76.077555 | 179 | 2.51 | 1.13 | 2.75 | -1.18 | -2.485 | 2.75 |
| 4 | 37.233776 | -76.077556 | 0 | -0.05 | 1.05 | 1.05 | 1.05 | -0.051 | 1.05 |
| 5 | 37.233785 | -76.077576 | 0 | 0.95 | -0.72 | 1.19 | -0.72 | 0.950 | 1.19 |
| 6 | 37.233767 | -76.077589 | 89 | -1.05 | -1.87 | 2.15 | 1.02 | -1.892 | 2.15 |
| 7 | 37.233781 | -76.077558 | 269 | 0.51 | 0.87 | 1.00 | 0.49 | -0.877 | 1.00 |
| 8 | 37.233752 | -76.07758 | 89 | -2.72 | -1.08 | 2.92 | 2.70 | -1.125 | 2.92 |
| 9 | 37.233778 | -76.077536 | 269 | 0.17 | 2.81 | 2.82 | 0.12 | -2.818 | 2.82 |
| 10 | 37.23375 | -76.077603 | 89 | -2.94 | -3.11 | 4.28 | 2.88 | -3.163 | 4.28 |
| 11 | 37.233767 | -76.077576 | 89 | -1.05 | -0.72 | 1.28 | 1.04 | -0.742 | 1.28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| N | 11 | Average: | 0.00 | 0.00 | 2.25 | 0.00 |
| DOF: 2N-1 | 21 | StDev: | 1.80 | 1.85 | 1.05 | 1.78 |

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are govenered by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:

$$P\left[d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n}\right] = \alpha$$

Setting the distance error equal to 10 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 10 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence | |
|---|---|---|---|
| x,y StDev | 1.8 | 2.4 | |

And the 95% confidence inteval of the positioning error is:

| | | | |
|---|---|---|---|
| Error | 3.5 | **4.7** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

Error: 5.1 **PASS**

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

Error 4.3 **FAIL**

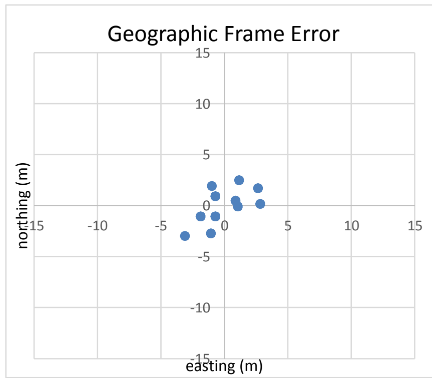



Figure 2: Contact position errors in a geographic refernece frame. Most contacts were reported east of the actual position.

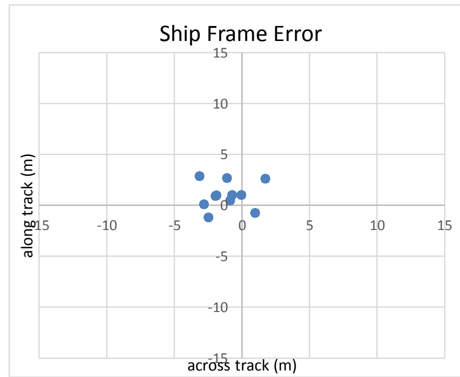



Figure 3: Contact position errors in a ship aligned refernece frame.

**NOAA Ship S222 2018  100m Range Scale Sidescan Calibration**
**Side Scan run on DN112.**

**2018 HSRR**
**S222 100m Range Scale**
**Side Scan Certification**

Figure 1: 2018 HSRR Side Scan Cert Site off Cape Henry

**MBES Position of Contact**

| | Lat | Long |
|---|---|---|
| | 37.2338032 | -76.0774818 |

| SSS Contacts | | | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 37.2337770 | -76.0774740 | | -2.91 | 0.69 | 2.99 | 0.69 | -2.911 | 2.99 |
| 2 | 37.233741 | -76.077494 | | -6.91 | -1.08 | 7.00 | -1.08 | -6.912 | 7.00 |
| 3 | 37.233823 | -76.077472 | | 2.20 | 0.87 | 2.36 | 0.87 | 2.200 | 2.36 |
| 4 | 37.233763 | -76.077445 | | -4.47 | 3.26 | 5.53 | 3.26 | -4.467 | 5.53 |
| 5 | 37.233778 | -76.077455 | | -2.80 | 2.37 | 3.67 | 2.37 | -2.800 | 3.67 |
| 6 | 37.233813 | -76.077558 | | 1.09 | -6.74 | 6.83 | -6.74 | 1.089 | 6.83 |
| 7 | 37.233834 | -76.077469 | | 3.42 | 1.13 | 3.60 | 1.13 | 3.422 | 3.60 |
| 8 | 37.233846 | -76.077475 | | 4.76 | 0.60 | 4.79 | 0.60 | 4.756 | 4.79 |
| 9 | 37.233834 | -76.07751 | | 3.42 | -2.49 | 4.24 | -2.49 | 3.422 | 4.24 |
| 10 | 37.233823 | -76.077466 | | 2.20 | 1.40 | 2.61 | 1.40 | 2.200 | 2.61 |
| 11 | | | | | | | | | |
| 12 | | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| N | 12 | Average: | 0.00 | 0.00 | 4.36 | 0.00 |
| DOF: 2N-1 | 23 | StDev: | 3.96 | 2.87 | 1.65 | 3.36 |

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are goverened by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:

$$P\left[ d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n} \right] = \alpha$$

Setting the distance error equal to 10 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 10 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence | |
|---|---|---|---|
| x,y StDev | 3.4 | 4.5 | |

And the 95% confidence inteval of the positioning error is:

| | | | |
|---|---|---|---|
| Error | 6.6 | **8.7** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

Error: 9.6 **PASS**

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

Error 7.6 **FAIL**

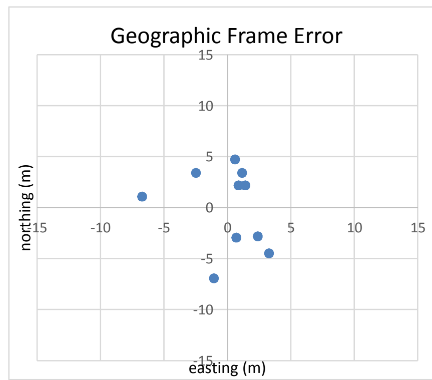



Figure 2: Contact position errors in a geographic refernece frame.  Most contacts were reported east of the actual position.

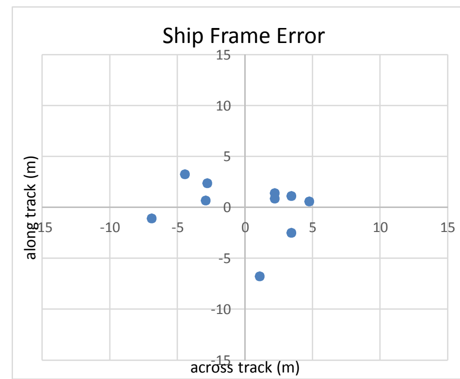



Figure 3:  Contact position errors in a ship aligned refernece frame.

Appendix 5.2: 2903 Echosounder Confidence Check

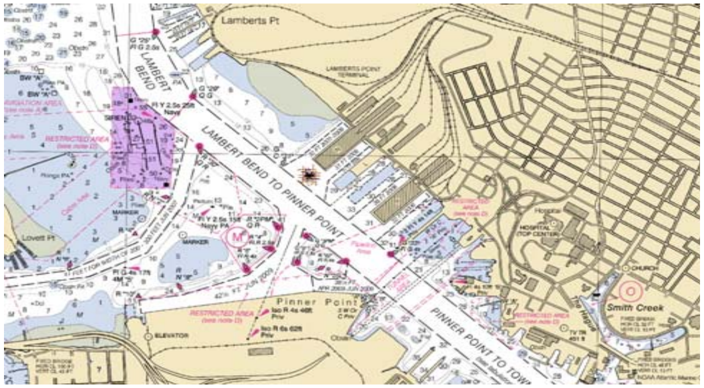
# 2903 Echosounder Confidence Check

NOAA HSL 2903 with new Kongsberg EM2040 MBES systems had completed a sonar acceptance test and confidence checks prior to the dates of use outlined in this report and the associated DR. The sonar system had been approved for use by Hydrographic Systems and Technology Report, but a full report had not been furnished to the ship.

This report will be updated upon completion of sonar acceptance and confidence checks.

Date valid: 2018-06-05

**NOAA Launch 2903 Sidescan Calibration - 50mRS**
**Side Scan run on Dn107. MBES not acquired.**




**MBES Position of Contact**

| | Lat | Long |
|---|---|---|
| | 36.865382 | -76.3204449 |

| SSS Contacts | | | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.8653980 | -76.3204610 | 090 | 1.78 | -1.43 | 2.28 | -1.43 | 1.778 | 2.28 |
| 2 | 36.865398 | -76.3204610 | 270 | 1.78 | -1.43 | 2.28 | 1.78 | 1.431 | 2.28 |
| 3 | 36.865384 | -76.3204730 | 090 | 0.22 | -2.50 | 2.51 | -0.22 | -2.498 | 2.51 |
| 4 | 36.865385 | -76.3204530 | 270 | 0.33 | -0.72 | 0.79 | 0.33 | 0.720 | 0.79 |
| 5 | 36.865385 | -76.3204530 | 090 | 0.33 | -0.72 | 0.79 | -0.33 | -0.720 | 0.79 |
| 6 | 36.865373 | -76.3204560 | 000 | -1.00 | -0.99 | 1.40 | -0.99 | -1.000 | 1.40 |
| 7 | 36.865398 | -76.3204610 | 180 | 1.78 | -1.43 | 2.28 | 1.43 | -1.778 | 2.28 |
| 8 | 36.865361 | -76.3204810 | 000 | -2.33 | -3.21 | 3.97 | -3.21 | -2.334 | 3.97 |
| 9 | 36.865398 | -76.3204610 | 180 | 1.78 | -1.43 | 2.28 | 1.43 | -1.778 | 2.28 |
| 10 | 36.865385 | -76.3204530 | 000 | 0.33 | -0.72 | 0.79 | -0.72 | 0.333 | 0.79 |
| 11 | 36.865385 | -76.3204530 | 000 | 0.33 | -0.72 | 0.79 | -0.72 | 0.333 | 0.79 |
| | | | | | | | | | |
| N | 10 | | Average: | 0.48 | -1.39 | 1.83 | -0.48 | | |
| DOF: 2N-1 | 19 | | StDev: | 1.30 | 0.81 | 1.02 | 1.49 | | |

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are goverened by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:
$$P\left[d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n}\right] = \alpha$$

Setting the distance error equal to 05 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 5 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence | |
|---|---|---|---|
| x,y StDev | 1.5 | 2.0 | |

And the 95% confidence inteval of the positioning error is:

| | | | |
|---|---|---|---|
| Error | 2.9 | **4.0** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

| | | |
|---|---|---|
| Error: | 3.0 | **PASS** |

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

| | | |
|---|---|---|
| Error | 3.8 | **PASS** |

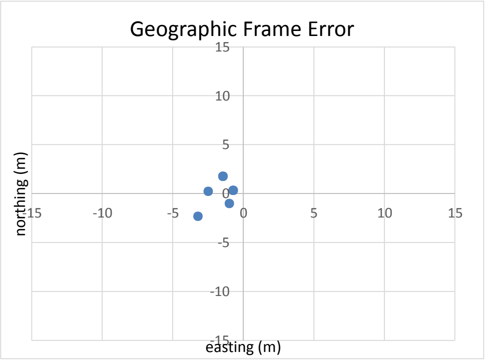



Figure 2: Contact position errors in a geographic refernece frame. Most contacts were reported southwest of the actual position.

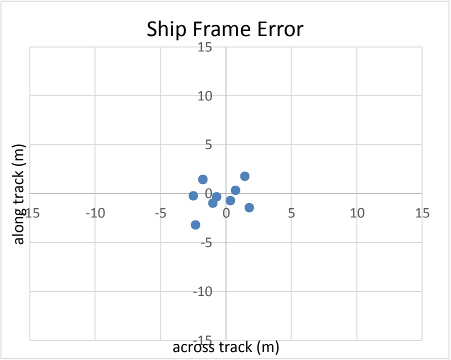



Figure 3: Contact position errors in a ship aligned reference frame.

**NOAA Launch 2903 Sidescan Calibration -75mRS**
**Side Scan run on Dn100. MBES not acquired.**

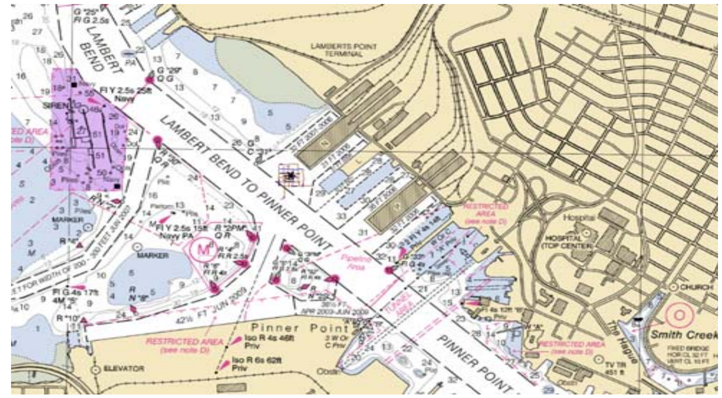



Figure 1. 1m$^3$ cube mobile target used to certify hull-mounted

**MBES Position of Contact**

| | Lat | Long |
|---|---|---|
| | 36.865382 | -76.320449 |

| SSS Contacts | | | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.8653670 | -76.3204520 | 000 | -1.67 | -0.27 | 1.69 | -0.27 | -1.667 | 1.69 |
| 2 | 36.865395 | -76.3204660 | 000 | 1.44 | -1.51 | 2.09 | -1.51 | 1.445 | 2.09 |
| 3 | 36.865367 | -76.3204520 | 180 | -1.67 | -0.27 | 1.69 | 0.27 | 1.667 | 1.69 |
| 4 | 36.865367 | -76.3204520 | 000 | -1.67 | -0.27 | 1.69 | -0.27 | -1.667 | 1.69 |
| 5 | 36.865395 | -76.3204660 | 180 | 1.44 | -1.51 | 2.09 | 1.51 | -1.445 | 2.09 |
| 6 | 36.865367 | -76.3204520 | 000 | -1.67 | -0.27 | 1.69 | -0.27 | -1.667 | 1.69 |
| 7 | 36.865376 | -76.3204450 | 090 | -0.67 | 0.36 | 0.76 | 0.67 | 0.356 | 0.76 |
| 8 | 36.865367 | -76.3204520 | 090 | -1.67 | -0.27 | 1.69 | 1.67 | -0.267 | 1.69 |
| 9 | 36.865373 | -76.3204890 | 090 | -1.00 | -3.56 | 3.69 | 1.00 | -3.556 | 3.69 |
| 10 | 36.865376 | -76.3204190 | 270 | -0.67 | 2.67 | 2.75 | -0.67 | -2.667 | 2.75 |
| 11 | 36.865376 | -76.3204450 | 090 | -0.67 | 0.36 | 0.76 | 0.67 | 0.356 | 0.76 |
| 12 | 36.865367 | -76.3204520 | 270 | -1.67 | -0.27 | 1.69 | -1.67 | 0.267 | 1.69 |
| N | 12 | | Average: | -0.84 | -0.40 | 1.86 | -0.59 | | |
| DOF: 2N-1 | 23 | | StDev: | 1.15 | 1.45 | 0.79 | 1.34 | | |

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are goverened by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:

$$P\left[d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n}\right] = \alpha$$

Setting the distance error equal to 05 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 5 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence | |
|---|---|---|---|
| x,y StDev | 1.3 | 1.8 | |
| And the 95% confidence inteval of the positioning error is: | | | |
| Error | 2.6 | **3.5** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

Error: 3.6 **PASS**

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

Error 3.4 **PASS**

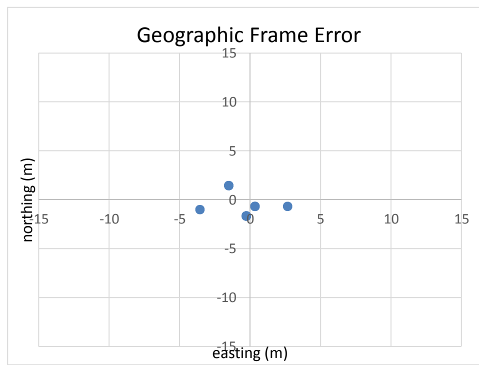



Figure 2: Contact position errors in a geographic refernece frame. Most contacts were reported southwest of the actual position.

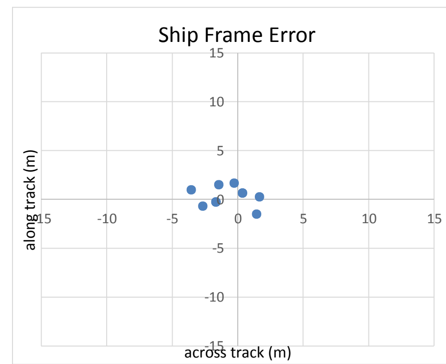



Figure 3: Contact position errors in a ship aligned reference frame.

# Appendix 5.3: 2904 Echosounder Confidence Check

## 2904 Echosounder Confidence Check

NOAA HSL 2904 with new Kongsberg EM2040 MBES systems had not completed sonar acceptance testing or confidence checks at the time of submission of this report.

HSL 2904 has not been used for any survey operations since installation of the new sonar systems.

This report will be updated upon completion of sonar acceptance and confidence checks.

Date valid: 2018-06-05

**NOAA Launch 2904 Sidescan Calibration - 50mRS**
**Side Scan run on Dn100.  MBES not collected.**

**MBES Position of Contact**

| | Lat | Long | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| | 36.865396 | -76.320495 | | | | | | | |
| **SSS Contacts** | | | | | | | | | |
| 1 | 36.8653930 | -76.3204840 | 310 | -0.33 | 0.98 | 1.03 | 0.98 | -0.333 | 1.03 |
| 2 | 36.865407 | -76.3204900 | 126 | 1.22 | 0.44 | 1.30 | -1.25 | -0.359 | 1.30 |
| 3 | 36.865401 | -76.3205070 | 40 | 0.56 | -1.07 | 1.20 | -1.17 | -0.260 | 1.20 |
| 4 | 36.865409 | -76.3204820 | 128 | 1.44 | 1.16 | 1.85 | -1.85 | 0.021 | 1.85 |
| 5 | 36.865392 | -76.3204790 | 308 | -0.44 | 1.42 | 1.49 | 0.53 | -1.395 | 1.49 |
| 6 | 36.865398 | -76.3205010 | 129 | 0.22 | -0.53 | 0.58 | 0.16 | -0.554 | 0.58 |
| 7 | 36.865403 | -76.3204900 | 220 | 0.78 | 0.44 | 0.90 | 0.16 | -0.882 | 0.90 |
| 8 | 36.865388 | -76.3204880 | 39 | -0.89 | 0.62 | 1.09 | 1.04 | -0.299 | 1.09 |
| 9 | 36.8654 | -76.3204840 | 218 | 0.44 | 0.98 | 1.07 | -0.50 | -0.952 | 1.07 |
| 10 | 36.865398 | -76.3204950 | 39 | 0.22 | 0.00 | 0.22 | -0.14 | 0.173 | 0.22 |
| 11 | 36.865395 | -76.3205010 | 39 | -0.11 | -0.53 | 0.54 | -0.53 | -0.111 | 0.54 |
| N | 10 | | Average: | 0.28 | 0.36 | 1.03 | 0.38 | | |
| DOF: 2N-1 | 19 | | StDev: | 0.71 | 0.80 | 0.46 | 0.74 | | |

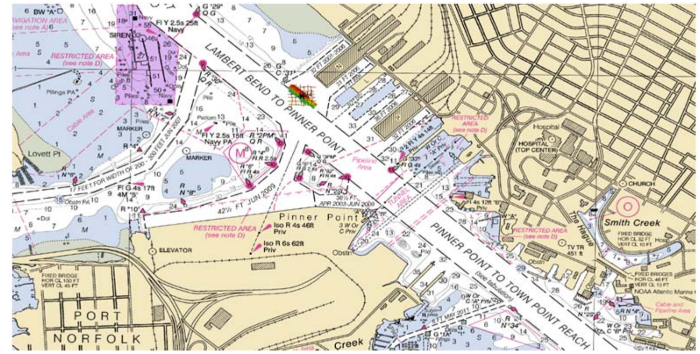



Figure 1. 1m$^3$ cube mobile target used to certify hull-mounted SSS on TJ HSL 2904.

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are goverened by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:

$$P\left[d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n}\right] = \alpha$$

Setting the distance error equal to 5 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 5 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence | |
|---|---|---|---|
| x,y StDev | 0.7 | 1.0 | |
| And the 95% confidence inteval of the positioning error is: | | | |
| Error | 1.5 | **2.0** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

Error: 2.1 **PASS**

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

Error 1.9 **PASS**

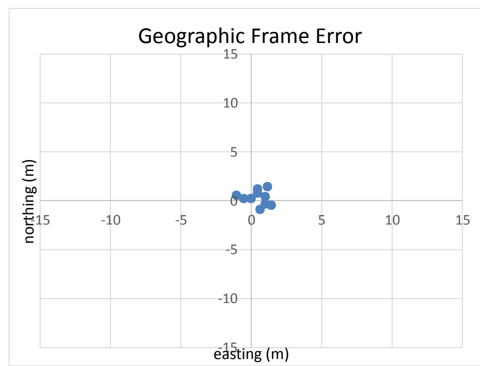



Figure 2: Contact position errors in a geographic refernece frame. Most contacts were reported southwest of the actual position.

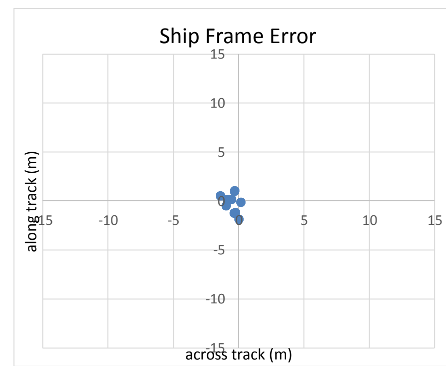



Figure 3: Contact position errors in a ship aligned reference frame.

**NOAA Launch 2904 Sidescan Calibration -75mRS**
**Side Scan run on Dn100. MBES not collected.**

**MBES Position of Contact**

| | Lat | Long |
|---|---|---|
| | 36.865396 | -76.320495 |

| SSS Contacts | Lat | Long | Line Hdg | Lat Diff (m) | Long Diff (m) | Dist. (m) | Along Trk (m) | Across Trk (m) | Dist. (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 36.8654100 | -76.3204680 | 224 | 1.56 | 2.40 | 2.86 | 2.40 | 1.556 | 2.86 |
| 2 | 36.865398 | -76.3204750 | 309 | 0.22 | 1.78 | 1.79 | 1.29 | -1.242 | 1.79 |
| 3 | 36.865392 | -76.3204910 | 39 | -0.44 | 0.36 | 0.57 | 0.56 | -0.122 | 0.57 |
| 4 | 36.865402 | -76.3204760 | 220 | 0.67 | 1.69 | 1.82 | -0.87 | -1.596 | 1.82 |
| 5 | 36.865408 | -76.3204870 | 127 | 1.33 | 0.71 | 1.51 | -1.49 | -0.234 | 1.51 |
| 6 | 36.865394 | -76.3204780 | 309 | -0.22 | 1.51 | 1.53 | 0.78 | -1.314 | 1.53 |
| 7 | 36.865386 | -76.3204870 | 310 | -1.11 | 0.71 | 1.32 | -0.39 | -1.259 | 1.32 |
| 8 | 36.8654 | -76.3204950 | 129 | 0.44 | 0.00 | 0.44 | -0.35 | -0.280 | 0.44 |
| 9 | 36.865397 | -76.3204760 | 311 | 0.11 | 1.69 | 1.69 | 1.19 | -1.202 | 1.69 |
| 10 | 36.865387 | -76.3204730 | 221 | -1.00 | 1.96 | 2.20 | -2.13 | -0.528 | 2.20 |
| 11 | 36.865405 | -76.3204870 | 220 | 1.00 | 0.71 | 1.23 | 0.10 | -1.223 | 1.23 |
| 12 | 36.865391 | -76.3204920 | 40 | -0.56 | 0.27 | 0.62 | 0.27 | -0.556 | 0.62 |
| N | 11 | | Average: | 0.17 | 1.15 | 1.46 | 0.73 | | |
| DOF: 2N-1 | 21 | | StDev: | 0.87 | 0.78 | 0.70 | 0.95 | | |

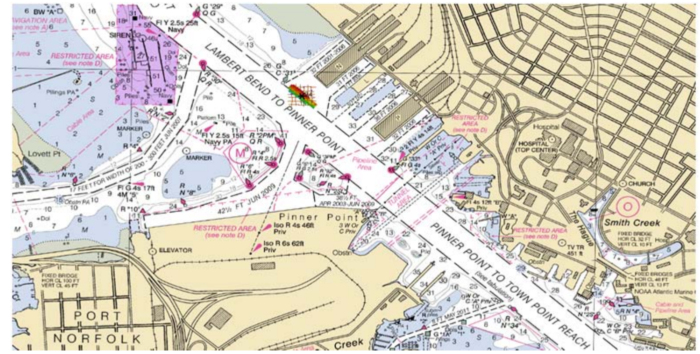



Figure 1. 1m[3] cube mobile target used to certify hull-mounted SSS on TJ HSL 2904.

Criteria: 95% Confidence that any future measurement will not give a positional error greater than 10 meters.

Assuming x and y errors are goverened by the same normal distribution, the square of the distance error is governed by Chi-squared statistics.

So:

$$P\left[d^2 > \frac{\sigma^2 \chi^2_{n;\alpha}}{n}\right] = \alpha$$

Setting the distance error equal to 05 meters and using the Chi-squared value for one degree of freedom and alpha = 0.05, solve for the maximum value for the true value of the standard deviation of the x and y error.

| | |
|---|---|
| Distance Error Limit (meters) | 5 |
| Max. x,y Std Deviation | 5.1 |

The sample estimate of the standard deviation will also be Chi-squared distributed

At a 95% confidence interval the standard deviation range is:

| | best est. | 95% Confidence |
|---|---|---|
| x,y StDev | 1.0 | 1.3 |

And the 95% confidence inteval of the positioning error is:

| | | | |
|---|---|---|---|
| Error | 1.9 | **2.5** | **PASS** |

Note: FPM method of 1.96*RMS standard deviation

| | | |
|---|---|---|
| Error: | 2.3 | **PASS** |

Alternate FPM method of mean radial distance plus 1.96*radial standard deviation

| | | |
|---|---|---|
| Error | 2.8 | **PASS** |

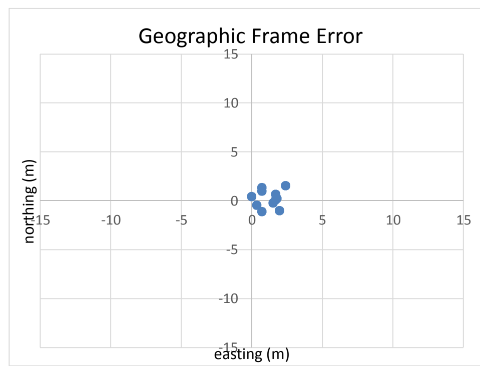



Figure 2: Contact position errors in a geographic refernece frame. Most contacts were reported southwest of the actual position.

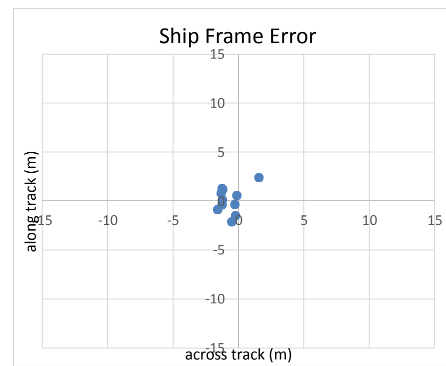



Figure 3: Contact position errors in a ship aligned reference frame.

# Appendix 6:

# Echosounder acceptance reports

Updated: 6/5/2018


# NOAA SHIP THOMAS JEFFERSON

# EM710 AND EM2040

# ACCEPTANCE TESTING

With Hydrographic Systems and Technology Programs
Multibeam Sonar Acceptance Procedures

DATES
2016 October 14 to 20

Glen Rice
NOAA Office of Coast Survey

# Executive Summary

A Kongsberg EM2040 multibeam and an EM710 MKII multibeam were installed aboard NOAA Ship *Thomas Jefferson* during an extended shipyard period at the Coast Guard yard in Curtis Bay in Baltimore, MD during the spring and summer of 2016. After a short stay at the Atlantic Marine Operations Center in Norfolk, VA, the ship proceeded with acceptance testing of the new survey systems in the areas between Norfolk and Hudson Canyon during the third week of October, 2016, with the assistance of Office of Coast Survey and Kongsberg personnel.

All portions of the Office of Coast Survey Sonar Acceptance Procedures were addressed, but the value of some tests were limited by the physical oceanography during testing. While working to confirm proper integration and operation of the new survey systems some important limitations to the installation were uncovered and characterized.

Key findings:

1. Both the EM2040 and EM710 are properly integrated with the supporting sensors.
2. A significant artifact presents itself in the outer beams of both multibeams. This artifact is transient and not motion correlated. While troubleshooting of this artifact is ongoing, at this time it is believed to be associated with the specific installation and not a defect in the hardware. Efforts to solve this problem include:
    a. Bringing the paint covering both transducers to Kongsberg specifications.
    b. Removing the fairlead forward of the transducer installation.

    It is not yet known if these efforts will resolve this artifact. In the interim it is recommended that the ship limit the survey swath to 45 degrees on either side by running in Single Sector mode, although the problem still persists at times even within the reduced swath.

3. A backscatter artifact persists on the port side as a small section of depressed backscatter and at 45 from vertical in the 200 kHz mode of the EM2040. Efforts to solve this problem include:
    a. Bringing the paint covering the EM2040 transducer to Kongsberg specifications.
    b. Removing filler material added during the previous shipyard to smooth the surface around the transducer.
    c. Lowering the EM2040 transmitter to meet current Kongsberg specifications.

    It is not yet known if these efforts will resolve this artifact.

4. A recommended Caris HIPS workflow had been provided to the ship. This recommended workflow is recognized as restricted to specific steps and integrating specific data to avoid post processing pitfalls.

While preliminary steps have been taken to remedy the problems described above, testing is still ongoing. Coast Survey plans to stay engaged in finding and implementing a solution to the described artifacts such that the survey systems can be used to their full potential.

# Contents

# 1 General Overview

The NOAA Ship *Thomas Jefferson* was dry docked in the U.S. Coast Guard Curtis Bay Shipyard in Baltimore, MD, during 2016 to replace a defunct Kongsberg EM1002 with a new Kongsberg EM710 MKII 1° x 0.5° multibeam echo sounder, and replace a pair of Reson 7125s with an EM2040. Coast Survey Hydrographic Systems and Technology Branch (HSTB) personnel were on board for the acceptance cruise to assist OMAO Marine Engineering with integration and testing of the new systems. The cruise departed from Norfolk, VA on Friday, 14 October 2016, and returned to Norfolk on Thursday, 20 October, with the ship traveling as far as the deep end of Hudson Canyon.

Originally the USNS *Littlehales*, NOAA Ship *Thomas Jefferson* (Figure 1) is a 63 meter long hydrographic vessel built by Halter Marine in 1991. Propulsion includes one main engine plus a bow thruster. An additional smaller drive on the main shaft is only used for maneuvering. *Thomas Jefferson* conducts bathymetric surveys in the Caribbean and the East Coast of the United States, generally in support of Office of Coast Survey. Other echo sounders on the ship include a bridge fathometer, Doppler speed log, and several Simrad ES60s. A Knudsen sub-bottom profiler transducer is mounted but has not been commissioned, and is thus not currently usable.


*Figure 1- NOAA Ship Thomas Jefferson in the Coast Guard yard.*

The Kongsberg EM2040 multibeam echo sounder is the second EM2040 in the NOAA fleet, but the first with the new “slim PU” design. This version should be supported for longer with firmware updates extending the usable life. The Kongsberg EM710 MKII multibeam echo sounder is the second of its kind in the NOAA Fleet, with one installed the previous year aboard NOAA Ship *Nancy Foster*. Both the EM710 and EM2040 were mounted on a new pod (Figure 2) on centerline and near the location of the old EM1002. Testing of the new echo sounders followed the HSTB Sonar Acceptance Procedures, version 1.0. Visiting personnel to support acceptance work included Glen Rice from HSTB, Neil Weston from Coast Survey, with Paul Johnson and Dr. Anand Hiroji from the University of New Hampshire Center for Coastal and Ocean Mapping. Anthony Dalheim from Kongsberg Underwater Technologies Inc. (KUTI) was also aboard to support installation and acceptance work.


*Figure 2- NOAA Ship* Thomas Jefferson *survey transducers from below and looking aft. The Kongsberg EM710 MKII 1° x 0.5° system includes the top two transducers in center pod, while the EM2040 system includes the bottom two. Also visible are the ES60 transducers in the pod on the right (port). The left (starboard) pod has an intake for an inboard surface sound speed sensor.*

# 2 Overview of schedule and conditions

## 2.1 Preplanning

Planning for the acceptance cruise evolved with the personnel involved and timing of the cruise. HSTB personnel coordinated with the ship's command and Coast Survey to establish a plan for acceptance testing. Eight days were allocated by Office of Marine and Aviation Operations for acceptance testing, including transit time.

1. Bow Mariner
2. Tom's Canyon
3. Hudson Canyon
4. South of Hudson Canyon
5. Deep Test Sites
6. Deep Noise Site
7. Multi-frequency Backscatter

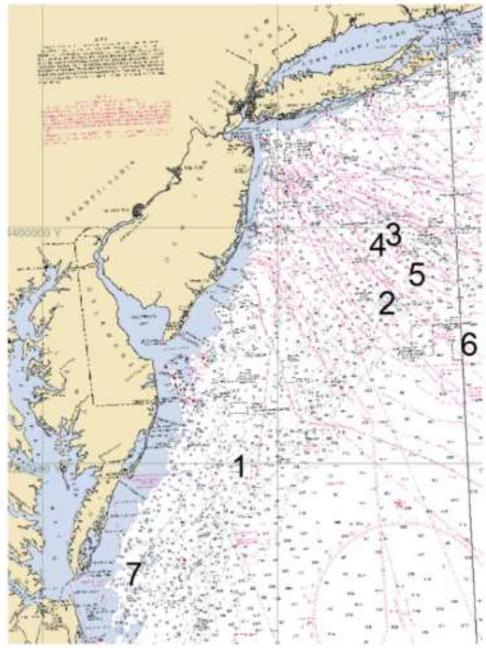



*Figure 3 - Acceptance testing planned locations as displayed on chart 13003.*

## 2.2 Executed Schedule

- Tuesday, 11 October – Rice Arrives aboard in Norfolk
- Wednesday, 12 October – Underway in Chesapeake Bay for crew familiarization. Some initial integration testing and interference testing with the EM2040.
- Thursday, 13 October – Initial attempt at a patch test but conditions are unsuitable. Shallow water noise testing, some tests with doppler speed log on.
- Friday, 14 October – Johnson, Hiroji, Weston and Dalheim arrive via small boat transfer to begin acceptance cruise.
- Saturday, 15 October –Second attempt at EM2040 Patch Test at Bow Mariner wreck site.
- Sunday, 16 October – Patch Test at Tom's Canyon for EM710 and EM2040, EM2040 Extinction Test at Hudson Canyon.
- Monday, 17 October – Extinction Test for EM710 and EM2040, EM710 Medium and Deep Accuracy Testing.
- Tuesday, 18 October – Extinction Test for EM710 and EM2040, deep noise test for EM2040 and EM710.
- Wednesday, 19 October – At Bow Mariner for EM2040 Accuracy, EM710 Shallow Accuracy, and EM710 and EM2040 Object Detection, EM710 and EM2040 Shallow Noise.
- Thursday, 20 October – Multispectral backscatter testing, arrive in port.

# 3 Pre-Installation Testing

## 3.1 Test Data Processing Workflow

NOAA Ship *Thomas Jefferson's* new survey system required a different configuration and slightly different workflow than was used for past NOAA Kongsberg systems. Other Kongsberg multibeams in the NOAA fleet have been configured with the reference point at the transmit transducer to overcome deficiencies in the treatment of lever arms in Caris HIPS for these systems ([1], [2]). *Thomas Jefferson* has two Kongsberg multibeam systems and they cannot both be identified as the primary reference point for the survey system. In June of 2016, HSTB conducted an analysis of the updated CARIS HIPS 9 ray tracing algorithm to confirm proper application of lever arms [3]. While this analysis showed the lever arm issue had been resolved, there are still post-processing impacts to the location of the reference point. This is discussed further in Section 7.1.

We also tested the application of the ellipsoid height from a raw Kongsberg *.all file using Caris 9.1 and Qimera 1.3. Thomas Jefferson has regularly used MarineStar with their POS M/V to provide real time ellipsoid heights that can be used directly, cutting down on post processing time. Heights are recorded within the Kongberg data both as the original NMEA string in the position record and as a separate height record. Testing demonstrated that when the GGA NMEA message was used the resulting depths were referenced to mean sea level (MSL). The GGA message format accommodates both the height relative to MSL as well as the separation to the ellipsoid used to derive MSL. However, the POS M/V does not populate the separation value in favor of higher precision elsewhere in the record, which means there is a lack of specification in the derivation of the datum. To avoid this ambiguity, *Thomas Jefferson* was configured to use the GGK message, which only contains ellipsoid heights. This was done with the intention that ellipsoid heights could be pulled directly into Caris through the *.all file without the need to merge additional positioning files, thus streamlining the path to survey on the ellipsoid. Testing in both Caris HIPS and Qimera 1.3.6 was successful in producing ellipsoid referenced results.

## 3.2 Determine data rates and file size

We estimated the anticipated data acquisition rate using the data collected during the extinction test (Section 6.5). The purpose of this analysis is to aid in the planning of appropriate storage volume for an anticipated survey. Data rates with and without water column files are described. Water column is recorded to a separate *.wcd file, but total water column rates should be considered the combined bathymetry and water column since both files are logged simultaneously. The bathymetry files contain a number of records, including backscatter, attitude, vessel offsets and settings, etc. No effort was made to quantify or predict the uncertainty associated with these estimates. The data rates strongly depend on depth. For example, the EM710 logs water-column data approximately 100 times faster in shallow water than in deep water. This means that continuous logging of full water column may be practical in deep water (e.g. for methane seep detection), but may be prohibitive in shallow water.

The EM2040 data collection rates without water column are shown in Figure 4.

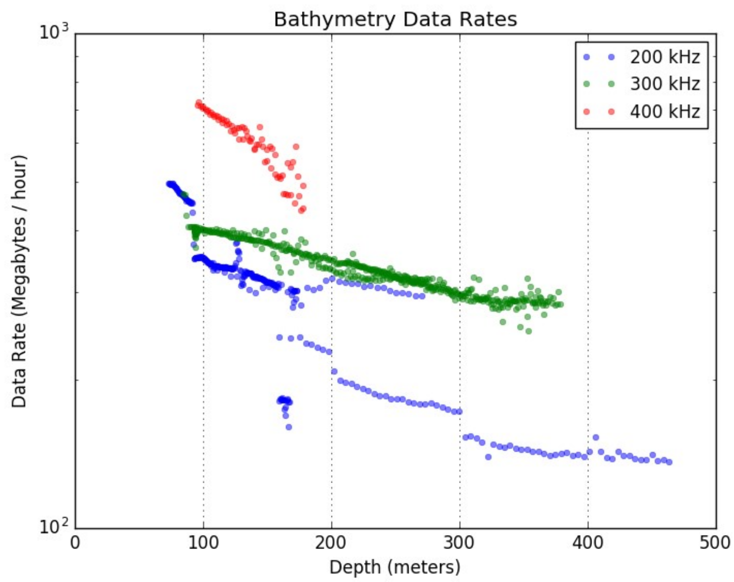



*Figure 4 - Data collection rates for the EM2040 without water column data.*

The EM2040 data collection rates with water column are shown in Figure 5.

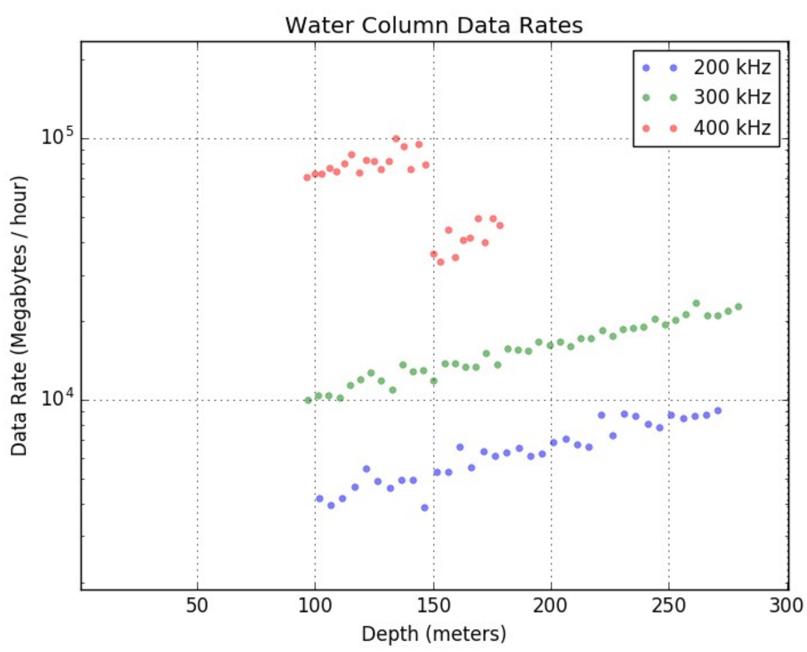



*Figure 5 - Data collection rates for the EM2040 with water column data.*

The EM710 data collection rates without water column are shown in Figure 6.

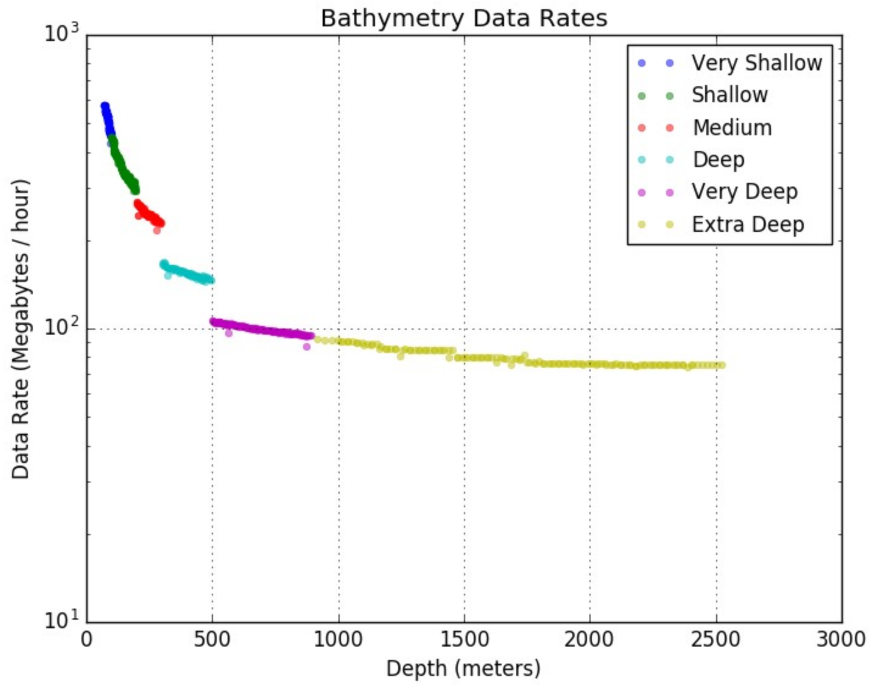



*Figure 6 - Data collection rates for the EM710 without water column data.*

The EM710 data collection rates with water column are show in Figure 7.

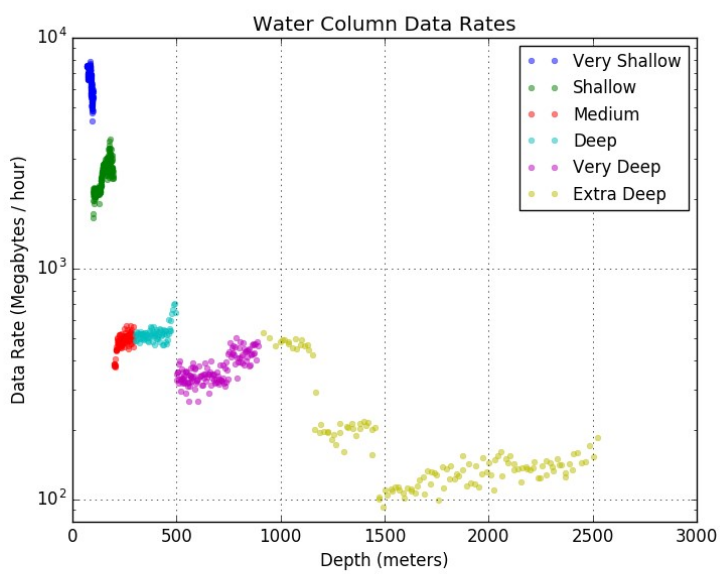



*Figure 7 - Data collection rates for the EM710 with water column data.*

## 3.3 Operational hazards

No current environmental or safety regulations or hazards restrict use of this multibeam echo sounder.

## 3.4 Determine user configurable system settings

The user configurable settings are as expected from past experience and relative to the SIS manual for an EM710 MKII and EM2040.

The EM2040 has an additional setting that had previously not been tested. It is possible to change the type of seafloor detection to "Min Depth", which allows for the better capture of small targets in the water column. The effects of this are discussed further in section 6.4.

# 4 Configuration

## 4.1 Sonar installation parameters

### 4.1.1 Vessel Survey and Reference Frames

Because *Thomas Jefferson* has two Kongsberg multibeams, the configuration successfully used on other platforms (i.e. setting the system reference point at the transmit array) could not work for both systems with a single POS/MV system. Because of the dual multibeam installation and only one possible primary reference point, the reference point was placed top dead center of the IMU, and all angular offsets were defined in the IMU frame.

Both of the EM710 transducers, RX and TX, are mounted in what Kongsberg considers a "forward" configuration. However, both of the EM2040 transducers are in what Kongsberg considers a "reversed" configuration. While this is not expected to cause problems with the current post processing software, historically the reversed configuration has caused complications and is worth noting.

The values used for lever arm offsets and angular rotations were based on the information provided by IMTEC, the survey company contracted by Kongsberg to conduct the vessel offset survey (included in appendix). Tables were provided for the ship reference frame, the IMU reference frame, the EM710 transmitter reference frame, and the ORU reference frame. The raw survey x-y-z locations in the survey reference frame were also provided. While the IMU reference frame table was used to describe all offsets and angles for the vessel configuration, the output from the IMU itself is rotated by the patch test values in SIS to bring it into alignment with the surveyed IMU frame.

While alongside in Norfolk an investigation into the vessel waterline using the draft marks, the vessel ellipsoid height, and a hull mounted sutron gauge was undertaken. A description of this work and results can be found in the appendix. In short, we validated that all methods of obtaining draft were consistent within their precision and that the bubbler gauge was the most precise.

The ship's underway settlement was also estimated while underway in Chesapeake Bay using ellipsoid relative techniques in HSTB's AutoQC tool. These results were comparable with past dynamic draft tests.

### 4.1.2 Data Flow Configuration

The data flow for a Kongsberg multibeam is multilayered. Multibeam data moves from the TRU to the SIS acquisition workstation. Data can be sent directly from SIS or from two other Kongsberg programs on the SIS workstation to an external client. While this flexibility provides many different options for configuration, it can also be confusing and easily confounded. The approach taken for this installation was mixed. The Kongsberg program, DataDistrobution.exe, was used to forward the multibeam data from the workstation to Hypack. This program has been designated to autostart when the SIS workstation is booted through the Windows Startup folder and must be allowed to run in the system tray or in the background at all times. If this program is closed, data will not be delivered to Hypack. Sound speed packets were sent from a lower level data distribution program to Velocipy.

The survey system was configured as described in Figure 8.

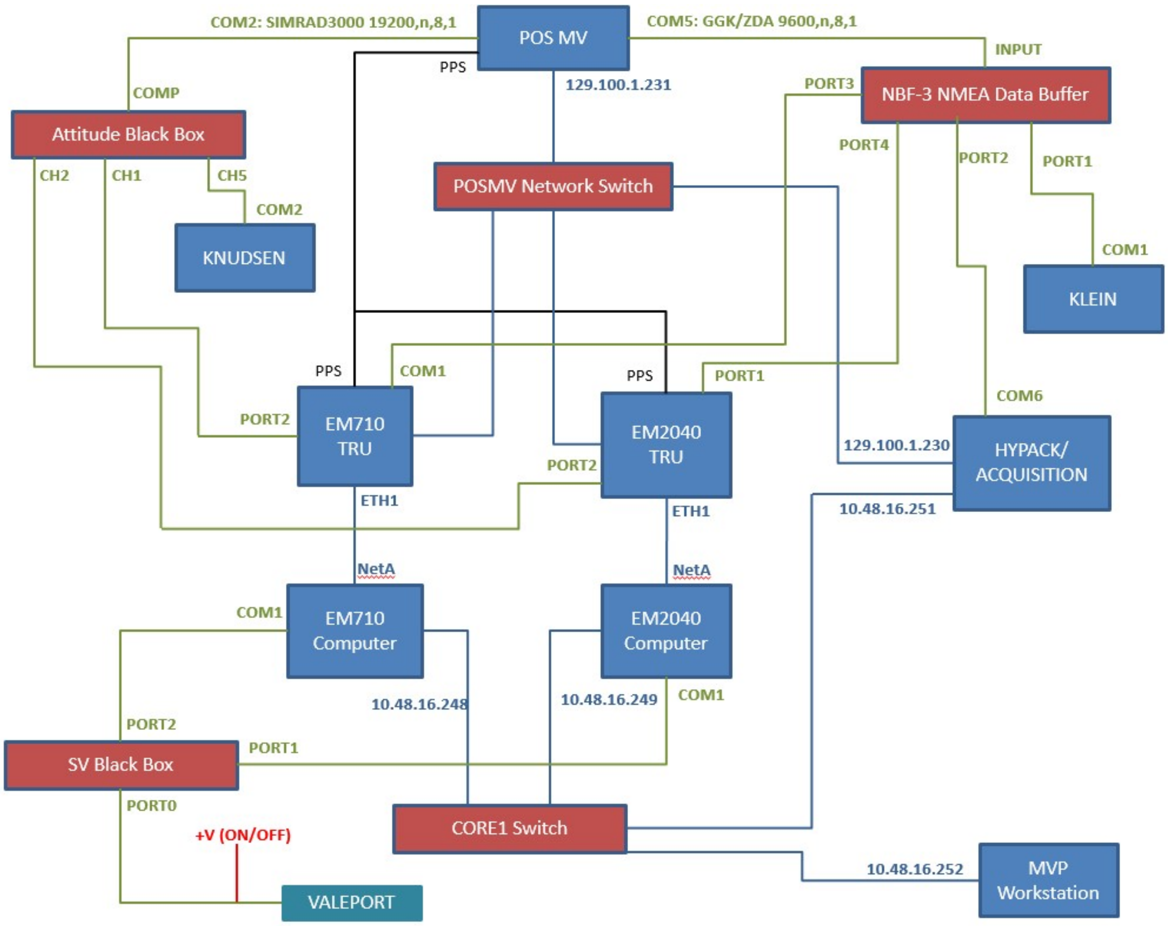



*Figure 8 - The Thomas Jefferson survey system configuration as of the acceptance cruise.*

Water column logging through SIS on both EM systems is licensed for the *Thomas Jefferson*. When water column is logged a separate raw *.wcd file containing water column records is produced. In addition, this file contains the attitude, position, system settings, installation parameters, and sound speed profiles. While these records are duplicates of some of the bathymetry file contents, these records make the independent use of the water column data easier as no pairing or merging between the *.all and *.wcd files is necessary.

A trigger cable to force the EM2040 to trigger from the EM710 transmit was built and installed by ship personnel as the request of the acceptance team. Triggering in this fashion causes the two systems to ensonify the same piece of the seafloor which is valuable to multi-frequency backscatter work. Enabling the trigger is completed within the EM2040 SIS software.

## 4.2 Ancillary equipment setup

### 4.2.1 Position and Attitude

The POS M/V was configured to send navigation (NMEA INGGK string) and attitude (Simrad 3000 (Tate-Bryant)) through serial cables to the TRU for each multibeam though unbuffered serial data splitters. An Ethernet connection from the POS M/V to each TRU was included for attitude velocity. The POS M/V lever arms and rotations were configured with the IMU as the reference point as described in 4.1.1. The POS M/V was checked to confirm proper connection to the primary / secondary antennas, and MarineStar support remained as previously configured. Position and attitude were compared between SIS and the POS M/V and were found to be equivalent. The POS M/V firmware for the PCS and GNSS cards could not be updated because the hardware was no longer under an Applanix maintenance contract.

### 4.2.2 Surface Sound Speed

There are three possible sources of surface sound speed aboard *Thomas Jefferson, however* both multibeams were configured to only receive data from the hull mounted Valeport sound velocity sensor during this cruise. The Valeport surface sound speed probe was configured to send an AML message directly to SIS and was confirmed to work as expected. A benefit of using the Valeport is that it is mounted on a seacock such that it can be retracted and removed for easy servicing (Figure 9). In addition to the Valeport, the ship has a TSG and a Reson sound speed sensor mounted in a flow through tank.

*Figure 9 – The Valeport in the retracted positon as mounted on a closed seacock. When the value is open the sensor is deployed by pushing down on the black handles.*

#### 4.2.3 Profiling the Physical Characteristics of the Water Column
An MVP with a CTD sensor was used during acceptance work. The sensor was compared with a recently calibrated Seabird CTD, as well as being compared with values from the Valeport surface sound speed sensor, located at hull depth, and found to be working properly.

Velocipy was configured to send new casts directly to SIS for both multibeams and to receive a message back noting that the cast was accepted by SIS. All cast extensions were made in Velocipy using either a deeper cast or the World Ocean Atlas.

Unfortunately, Casttime was not functioning during the cruise. While Casttime was configured and working before leaving port, some configuration change that remained undetermined caused Casttime not to receive cast information from the MVP. Had Casttime been running, some of the problems experienced during this cruise may have been alleviated. It was expected that ship personnel would resolve this problem at a later date.

#### 4.2.4 Hypack
Hypack was configured to accept data from SIS for real time display and communication with the bridge only. For these tests, all multibeam data were logged through SIS. We recommend that SIS be used for all future operational data logging as well.

#### 4.2.5 Vertical control
Generally, the vertical reference for acceptance work was either the real time water level or the ellipsoid depending on the requirement for a consistent vertical reference for the seafloor depth. The ITRF 2008 ellipsoid was realized through MarineStar integration with the POS M/V which was recorded both in the POS M/V files and in the Kongsberg *.all files. Where a comparison to previous surveys was required, VDatum was used to shift from the ellipsoid to the applicable datum.

# 5 Alongside Testing

## 5.1 User interface and system control
The user interface and system controls for the EM710 and EM2040 operated the same as for previous versions of SIS. SIS 4.3.2 was installed on the EM2040, and SIS 4.3.0 was installed on the EM710. Minor changes to SIS are EM model specific, and these two versions are essentially the same.

## 5.2 System health self-tests
SIS Built In Self Tests (BIST) of all types were performed for both systems, including the extended tests available through the TRU. While all BIST tests passed, a single receiver channel (number 52) on the EM2040 showed a significantly different response, indicating a possible broken channel.

## 5.3 Evaluate stave data
See the discussion of BIST tests in 5.2.

## 5.4 Backscatter quality assessment
Backscatter quality was not assessed while alongside. Please see 6.6 for a discussion of backscatter assessment and normalization while underway.

# 6 Underway Testing

## 6.1 Patch Test

Patch testing was attempted in two separate locations but completed for both systems over Tom's Canyon, approximately 100 nm SE of New York City. We attempted to complete the patch test of the EM2040 over the wreck of the Bow Mariner. Because the wreck tests lead to inconclusive results the ship moved to Tom's Canyon and patch tested both systems simultaneously. This location had been used previously for patch testing the EM710 from NOAA Ship *Nancy Foster*. The 60 meter drop from 120 meters to 180 meters proved to be a good target for pitch and yaw lines. Roll lines were conducted on top of the shelf just above the canyon, and confirmation lines were run across the canyon in a deeper section. Patch test values are described for both systems in Table 1.

*Table 1 - Patch test values for both multibeams.*

| *All values are in degrees* | EM2040 | EM710 |
|---|---|---|
| Roll | 0.07 | 0.02 |
| Pitch | -0.05 | -0.05 |
| Yaw | 0.70 | 0.05 |

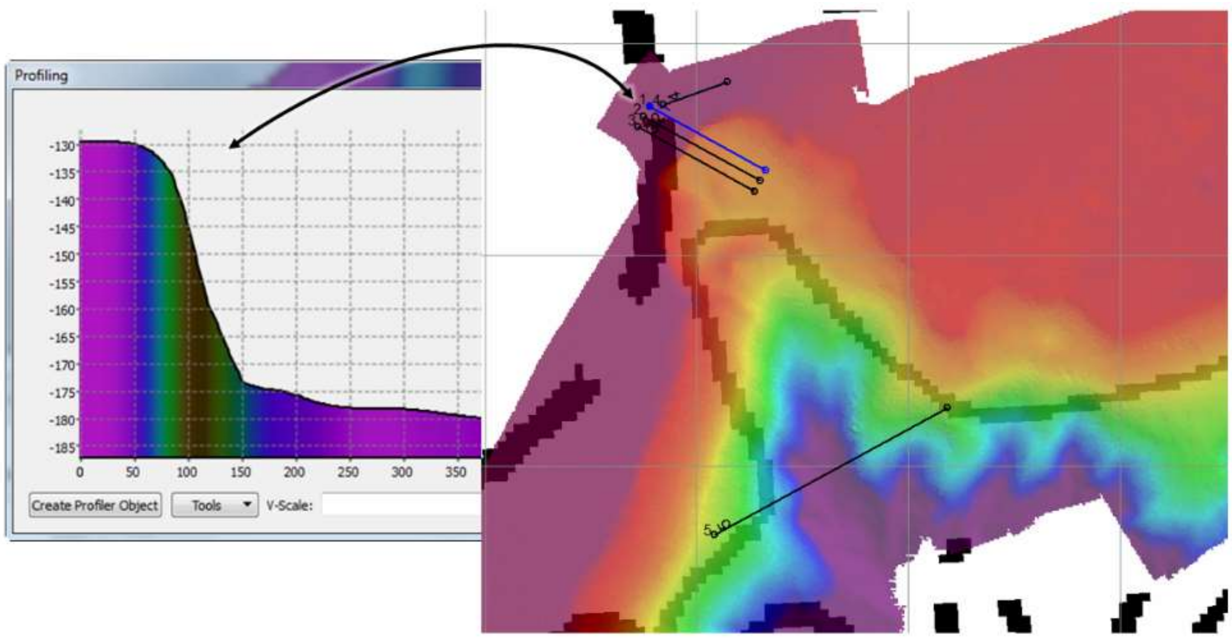



*Figure 10 - The patch test lines at Tom Canyon. On the left is a profile of the pitch line. On the right is an overhead view of the relief and patch test lines. Line 2 is pitch, 1 and 3 were for yaw, and 4 was for roll. Line 5 is the confirmation line, with the maximum depth being at 450 meters.*

We calculated an attitude time delay of 10 ms using the correlation of roll rate with swath slope artifact as described in [4] using transit data from the EM2040 acquired after the Tom's Canyon patch test. There were significant artifacts in the bathymetry as described in section 6.4, which reduce confidence in this estimate. EM710 noise was such that no estimate could be made with the same set of lines. Subsequent work to improve the estimated time delay from the EM2040 data increased the estimate to 11 ms (Figure 11) with a reported uncertainty of 2 ms at two standard deviations from the covariance matrix used for line fitting. Similar work to extract a time delay for the EM710 resulted in similar values to the EM2040. This time delay is entered in to SIS for both multibeams and the SIS recorded attitude data time stamp is shifted accordingly for post processing. This time delay is different than the 14 ms offset found with both NOAA ships *Rainier* and *Fairweather* but is sufficient until the outer beam artifacts are removed and a better estimate can be made. The root cause of this time delay on this and other systems remains unknown.

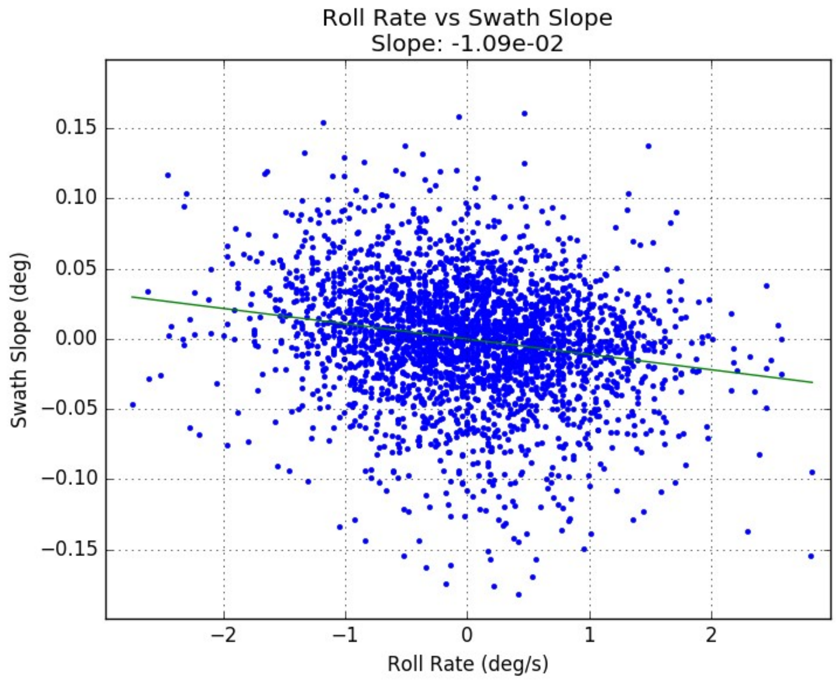



*Figure 11 - Roll Rate to Swath Slope Correlation for the EM2040. Green line is a linear fit.*

## 6.2 Acquire Reference Data Set

Three reference datasets in different depths were acquired for the EM710. One of these locations was used for the EM2040 as well. These data are used to check for bathymetric biases across the swath by comparing survey data with a dense reference surface. The IHO uncertainty standards (and similarly the NOAA specification) contain both a depth dependent and depth independent error component; the depth independent part (*a* in Equation 1) is intended to account for error sources such as vertical control and draft measurement, the depth dependent factor (*b* in Equation 1) accounts for integration, environmental, and echo sounder performance .

*Equation 1: Vertical uncertainty limit equation from both IHO and NOAA Specifications.*

$$Uncertainty\ Limit = \sqrt{(a^2) + (b * d)^2}$$

Because of the nature of these tests, the depth independent error parameters were not much varied, so it is more appropriate to evaluate the performance only against the depth dependent component (i.e. the ‘b’ parameter). For both IHO order 1 and NOAA Specifications, this is 1.3% of water depth.

**EM2040 ACCURACY TESTING**

The area to the north of the wreck of the Bow Mariner was used for the reference surface. This area is flat and generally ~75 meters deep (Figure 12). 200 kHz, 300 kHz and 400 kHz modes were tested. Weather was 15 to 20 knots with seas 2 to 3 feet and with swells also 2 to 3 feet. Current was from the north causing a set of approximately 6 degrees of heading when on line. A number of artifacts were observed during these tests. The combined effect of which obscured identification of any one problem. One of these problems was variable sound speed (Figure 13) at depth during testing. This variability may have been caused by the propagation of internal waves. This impacted the performance of EM2040 during this test, causing a larger apparent uncertainty than would be experienced during more stable oceanographic conditions. Another artifact was a periodic, but non-motion correlated, leeward outer beam artifact that is still being investigated. This artifact is discussed in more detail in section 6.4. The reference surface was created from the object detection lines filtered to remove outer beam noise. This analysis was conducted by accumulating data from several lines with opposing headings.

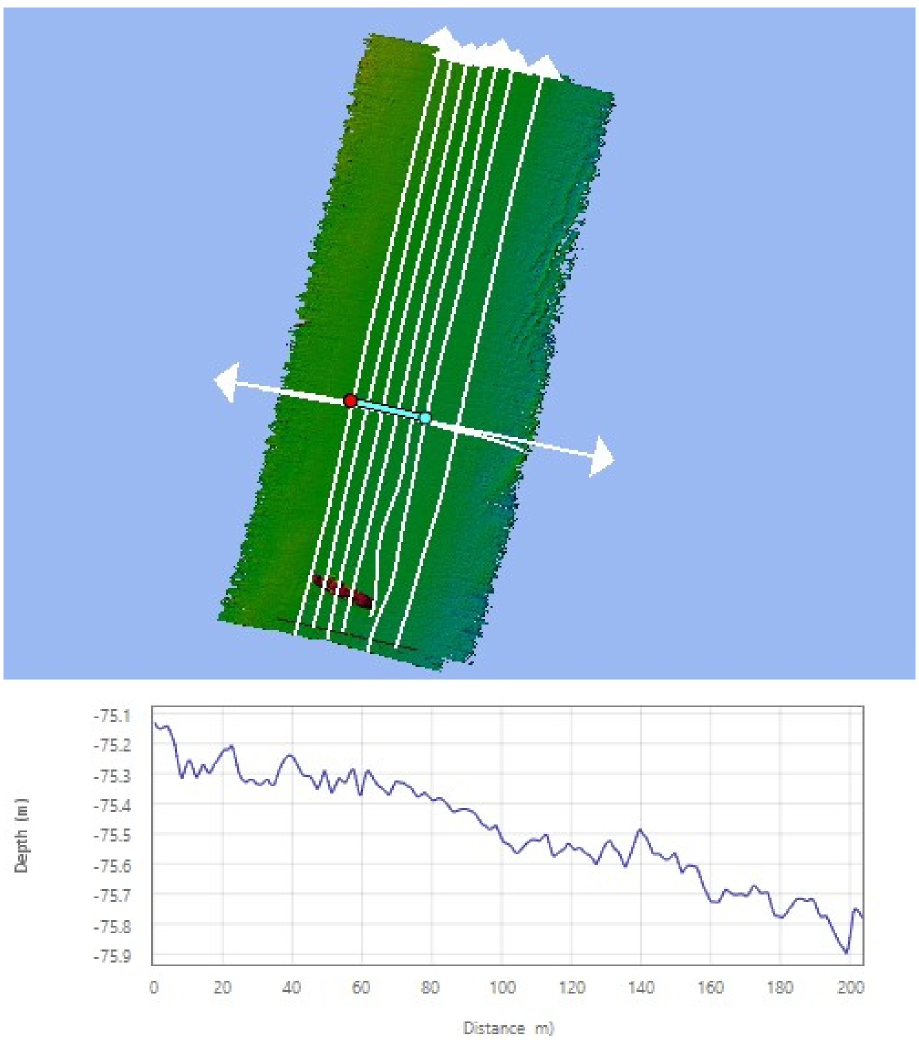



*Figure 12 - The accuracy test site at the Bow Mariner. Accuracy data were extracted along the profile (blue line in top, plot in bottom). The wreck can be seen as red in the bottom of the surface. Depths are relative to mean lower low water.*

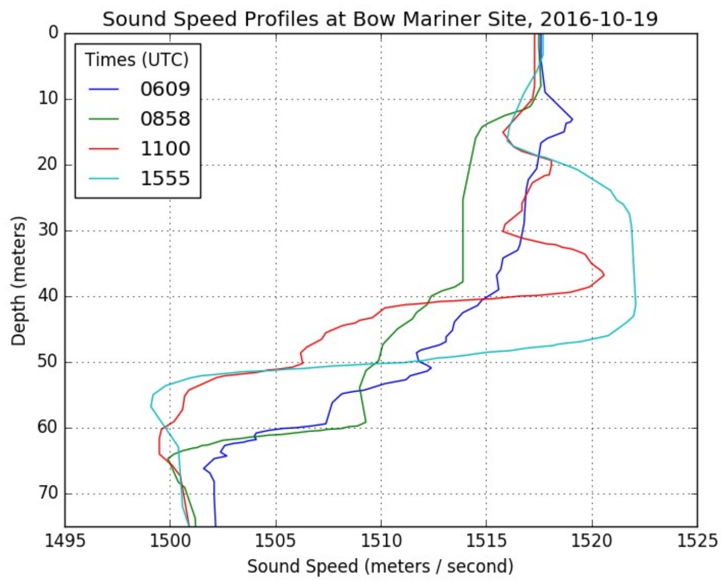



*Figure 13 – Sound Speed Profiles at the Bow Mariner site during object detection and accuracy testing. There are significant changes in these casts between 10 meters and 60 meters of water depth.*

The comparison between these data was conducted on the ellipsoid in Qimera 1.3.6.

The 400 kHz mode had a mean bias of less than 0.3% of water depth, which equates to 0.23 meters in 75 meters of water. While the pulse length was set to adjust automatically, during the 400 kHz tests the pulse length was 107 microseconds with a CW pulse. A sound speed artifact is evident in the outer swath due to the dynamic oceanographic conditions. Soundings fell within 0.6% of the mean difference at two standard deviations. Note the maximum swath angle for the 400 kHz mode is restricted 60 degrees on each side. While these results meet expectations, these statistics should improve in more ideal oceanographic conditions.

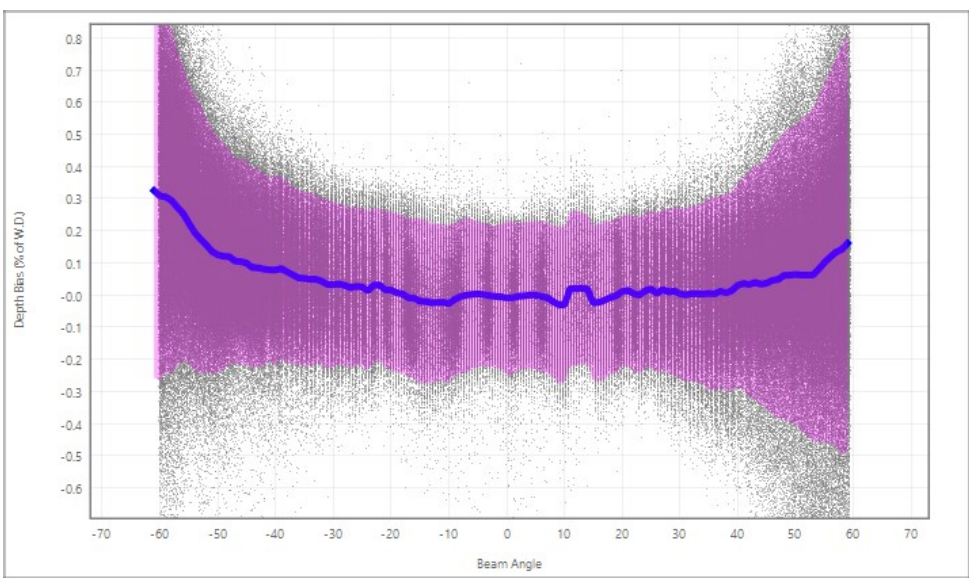



*Figure 14 – EM2040 400 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and these data. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.*

The 300 kHz mode had a mean bias at nadir of less than 0.1% of water depth, which equates to 0.08 meters in 75 meters of water. While the pulse length was set to adjust automatically, during the 300 kHz tests the pulse length was 370 microseconds with an FM pulse. A sound speed artifact is evident in the outer swath due to the dynamic oceanographic conditions. Soundings approximately within 1.0% of the mean difference at two standard deviations inside a 130° opening angle. While these results meet expectations, these statistics should improve in more ideal oceanographic conditions and once the additional artifact is resolved.

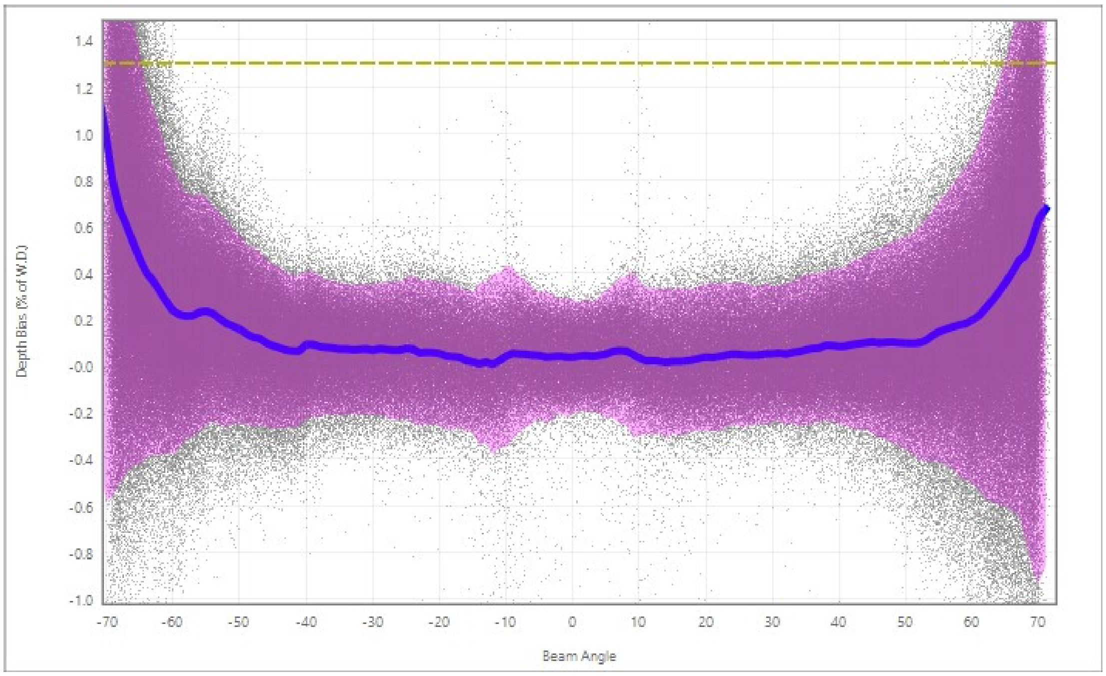



*Figure 15 – EM2040 300 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.*

The 200 kHz mode had a mean nadir bias of less than 0.1% of water depth, which equates to 0.08 meters in 75 meters of water. The pulse length was set to adjust automatically, and during the 200 kHz tests the pulse length was between 431 and 517 microseconds with an FM pulse. A sound speed artifact is evident in the outer swath due to the dynamic oceanographic conditions. Soundings were approximately within 1% of the mean difference at two standard deviations and inside 130° opening angle. While these results meet expectations, these statistics should improve in more ideal oceanographic conditions and once the additional artifact is resolved.

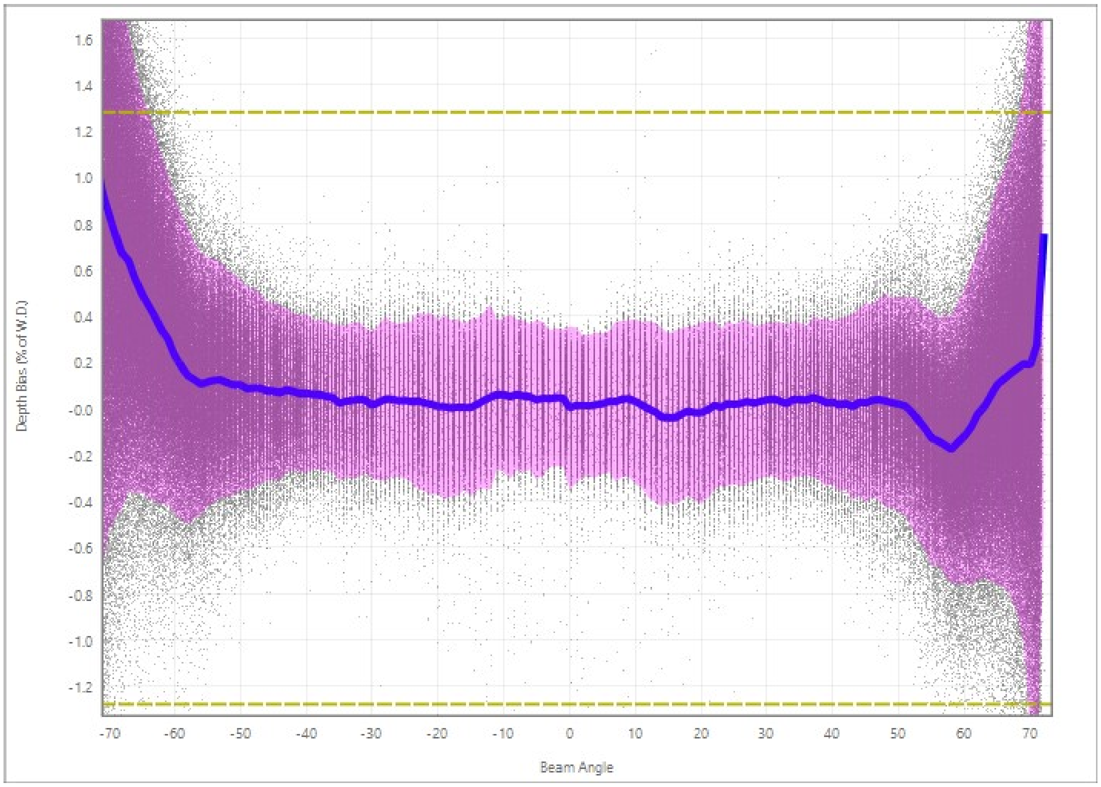



*Figure 16 – EM2040 200 kHz accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. IHO Order 1 is 1.3% for this location.*

### EM710 ACCURACY TESTING

Three separate areas were used for accuracy testing of the *Thomas Jefferson* EM710 MKII. The modes Shallow, Very Shallow, and Medium were tested at the same Bow Mariner site used for the EM2040. Sound speed problems as discussed in the EM2040 section for the Bow Mariner site are also present for the EM710. The EM2040 reference surface was used for the test, and was constructed from the EM2040 object detection data as described previously. The 70 meter mean depth for this area would normally be collected in Very Shallow mode which is used by the EM710 MKII systems in automatic mode for depths between 0 and 100 meters.

Flat areas in the proper depths suitable for accuracy testing of the deeper modes are rare within a reasonable steaming distance from Norfolk, VA and also not in the Gulf Stream. Areas near the extinction line and just sound of Hudson Canyon were used for these deeper modes. These sites had less than a 3° slope that ran across the reference surface. Because there were fishing vessels in the area and this work was conducted at night, the MVP was not towed. Medium and Deep modes were tested at more than one location to help provide some continuity between the locations.

Deep and Medium mode were tested in approximately 200 meters of depth (Figure 17). A CTD to 170 meters was taken at the medium depth site upon arrival. The 200 meter mean depth at this site would normally be collected in either Shallow mode, optimized for depths between 100 to 200 meters, or in Medium mode, good from 200 to 300 meters water depth.

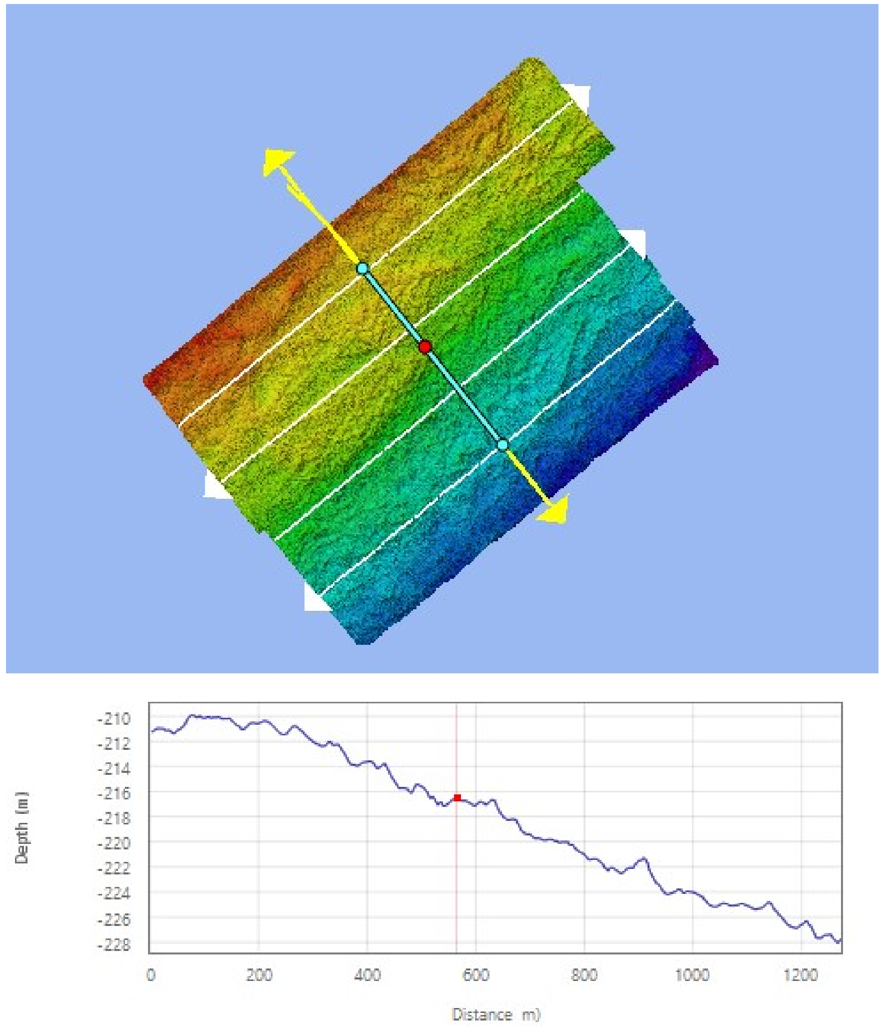



*Figure 17 – The EM710 medium depth accuracy test site. Accuracy data were extracted along the profile (blue line in top, plot in bottom). Depths are to the ellipsoid.*

Deep, Very Deep and Extra Deep were tested in approximately 550 meters of water (Figure 18). A CTD cast to a depth of 300 meters was taken in 600 meters of water with the extended point being interpolated linearly from the last section of the water mass. The 550 meter mean depth for this area would normally be collected in Very Deep mode which is optimized for depths between 500 and 1000 meters.

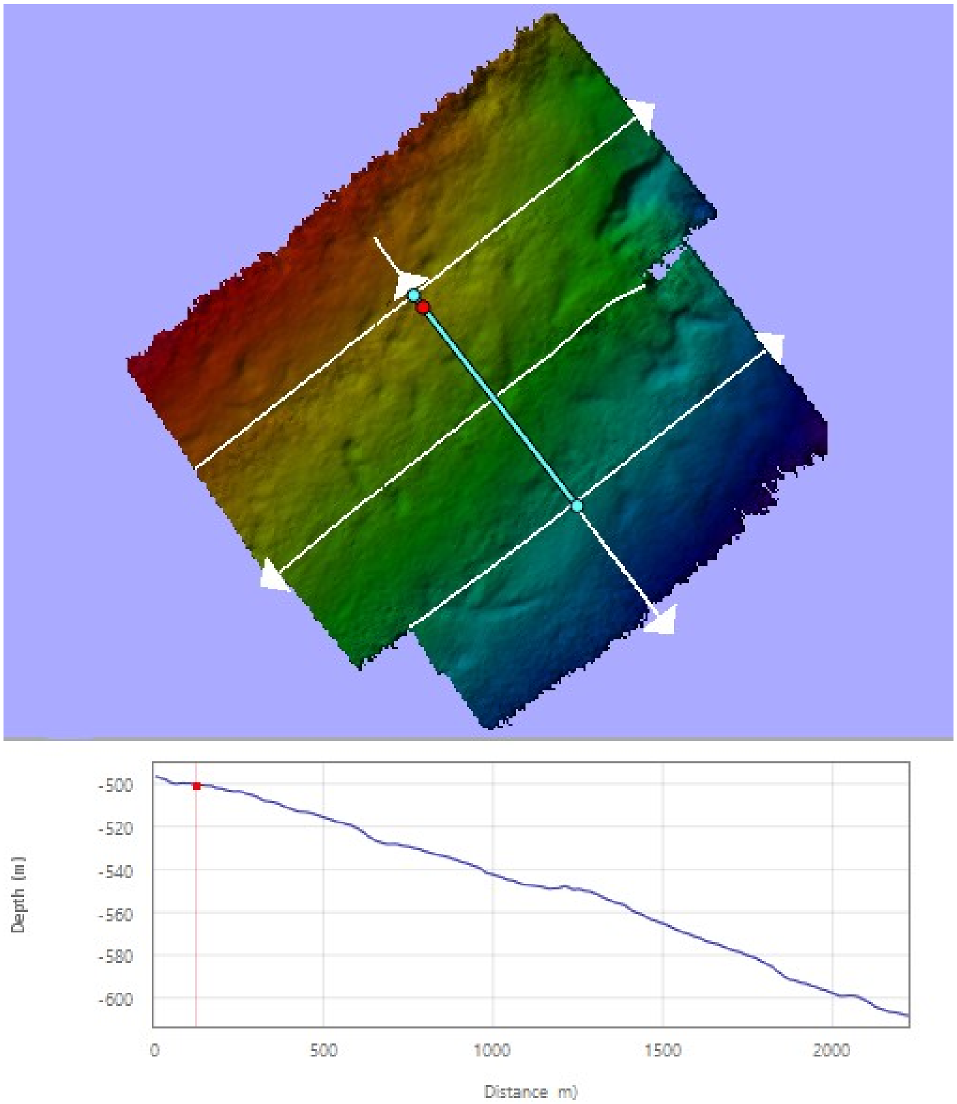



*Figure 18 - The EM710 deep accuracy test site. Accuracy data were extracted along the profile (blue line in top, plot in bottom). Depths are to the ellipsoid.*

*Table 2 - A summary of the test location for each mode.*

| Mode | Shallow Site | Medium Site | Deep Site |
|---|---|---|---|
| Very Shallow – Single & Dual Swath | ✓ | | |
| Shallow – Single & Dual Swath | ✓ | | |
| Medium – Dual Swath | ✓ | ✓ | |
| Medium – Single Swath | | ✓ | |
| Deep – Dual Swath | | ✓ | ✓ |
| Deep – Single Swath | | ✓ | |
| Very Deep – Single Swath | | | ✓ |
| Extra Deep – Single Swath | | | ✓ |

Very Shallow mode was tested in both single and dual swath with each displaying the same characteristics. Figure 19 shows the results for dual swath mode.

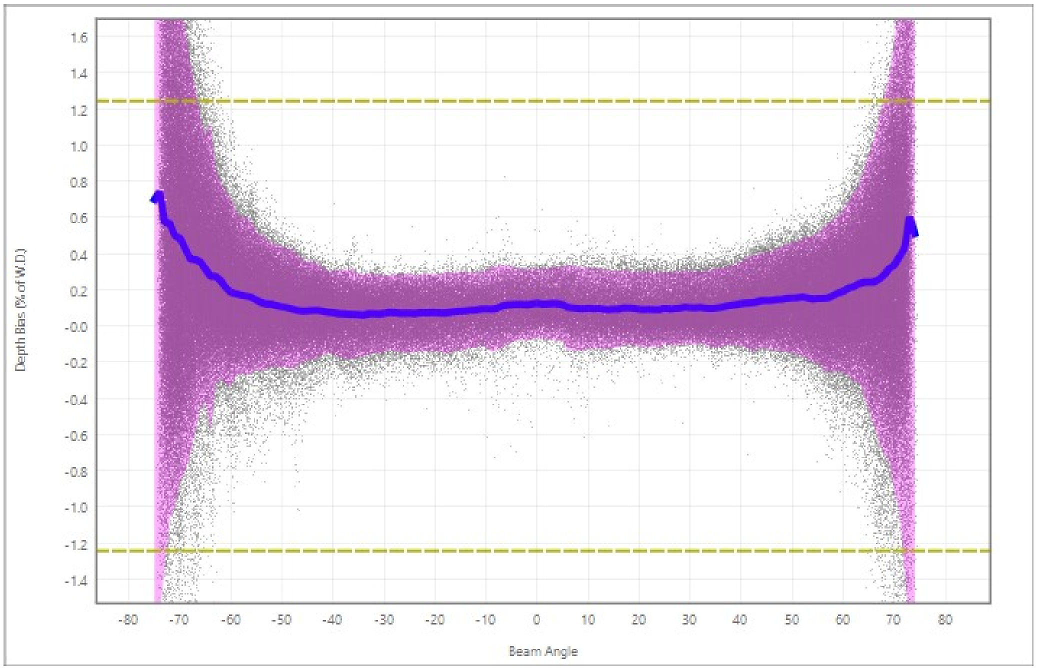



*Figure 19 - EM710 Very Shallow Dual Swath mode accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.*

Shallow mode was also tested in both Single and Dual Swath in the same location with similar results. Some noise is evident in the near-nadir region for this mode (Figure 20).

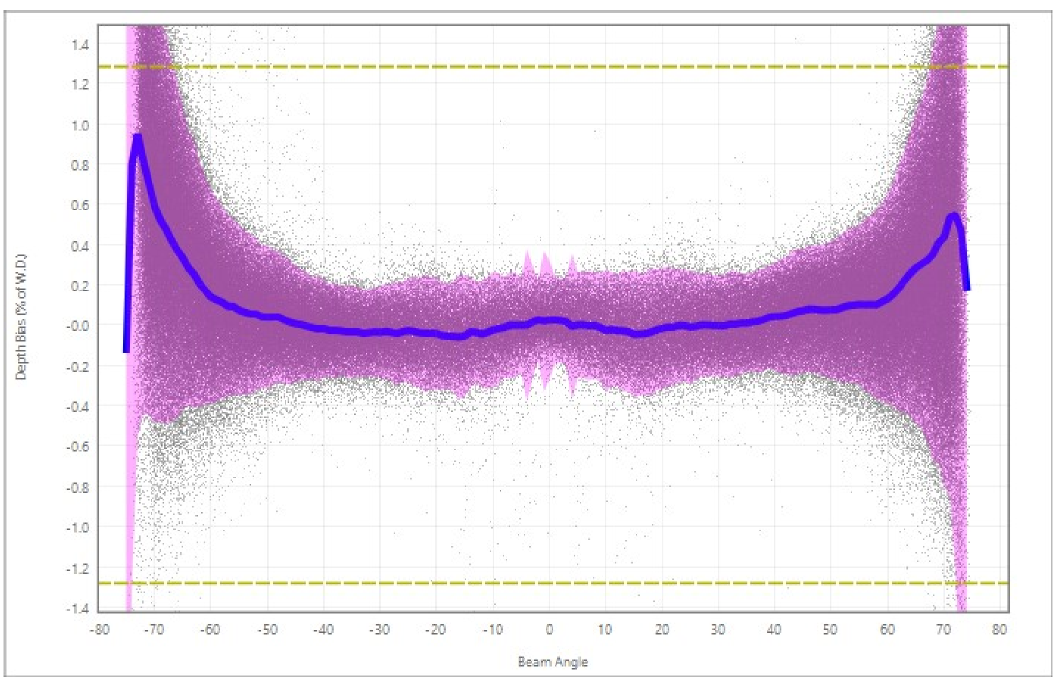



*Figure 20 - EM710 Shallow Dual Swath mode accuracy results as a percent of depth. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.*

Medium mode was tested at both the Bow Mariner (shallow) site and at the medium depth site (Figure 21, Figure 22). The results from these two locations were comparable, with more noise near nadir evident at the shallower location. To reduce the effect of the sound speed artifact at the medium site, we filtered the crossline to within +/- 15 degrees of nadir and generated the reference surface with these filtered lines. We then used the main scheme lines to compare to the reference surface. Because the main scheme lines were acquired closer to the time of the cast, they had less of an artifact. By restricting the data collected later (cross lines) to the near nadir region and using the data collected closer in time to the cast (main scheme lines) the effects of sound speed are reduced. In some cases there was significant nadir noise that was not displayed directly in the plot, but was reflected in the standard deviation (pink) part of the plot.

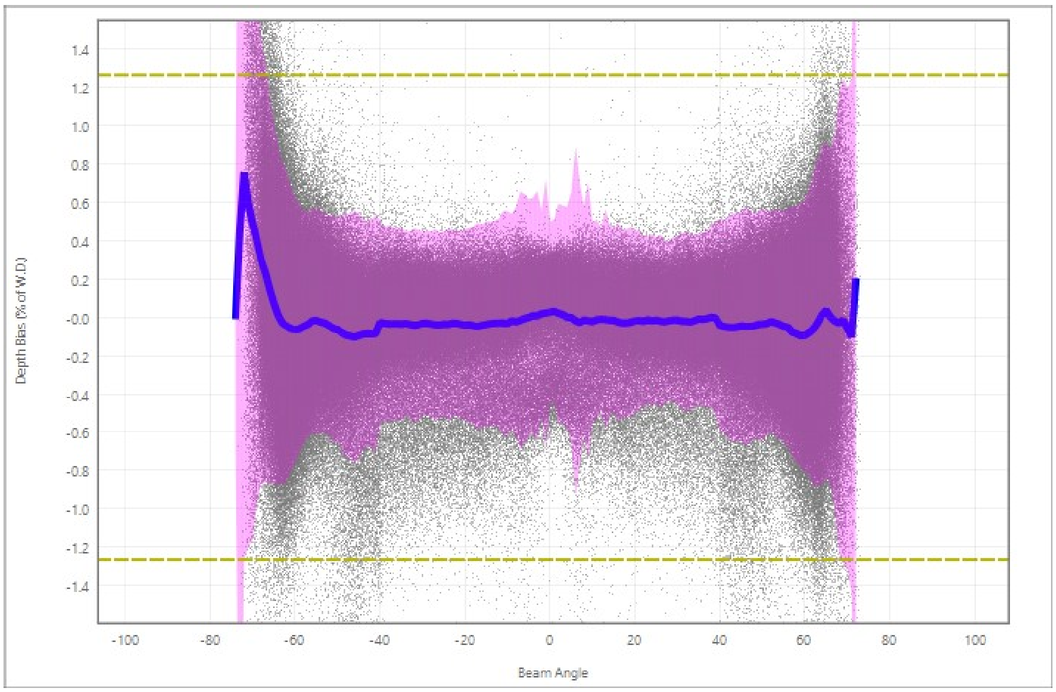



*Figure 21 - EM710 Medium Dual Swath mode accuracy results as a percent of depth at the Bow Mariner site (75 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.*

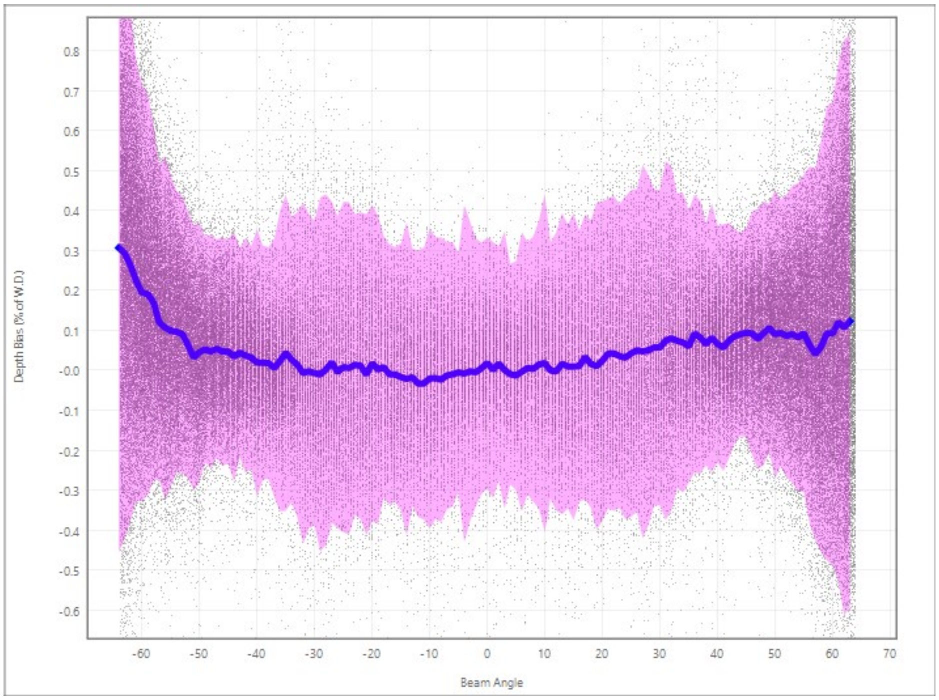



*Figure 22 - EM710 Medium Dual Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The crosslines have been used to make a small nadir-only surface and compared to the main scheme lines. The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.*

Unfortunately, the same approach to reducing the sound speed effects cannot be used for deep mode at the medium depth site since the main scheme lines were collected in medium mode. Deep mode was tested in both Single and Dual Swath modes. Dual Swath mode showed significant nadir noise (Figure 23), while Single Swath mode show a large increase in noise in the starboard sector (Figure 24).

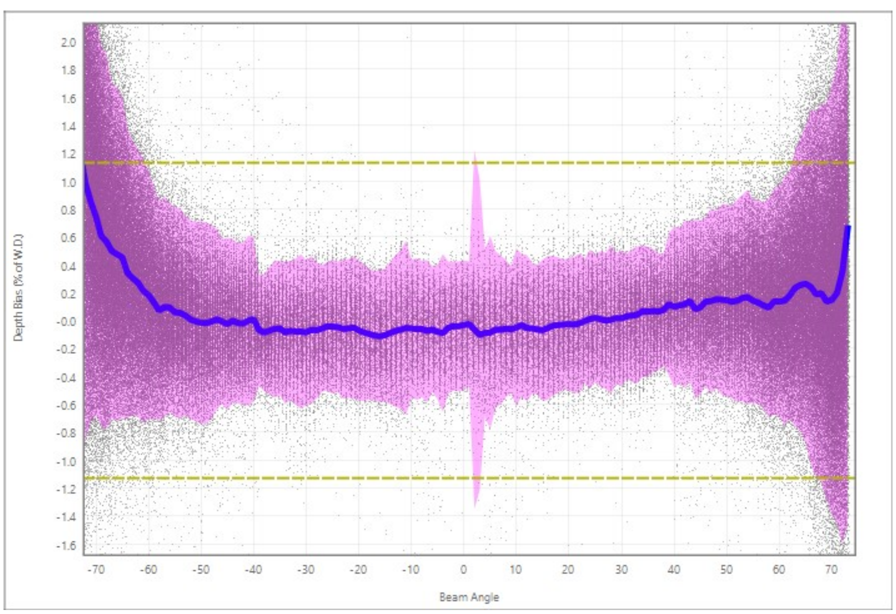



*Figure 23 - EM710 Deep Dual Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean.*

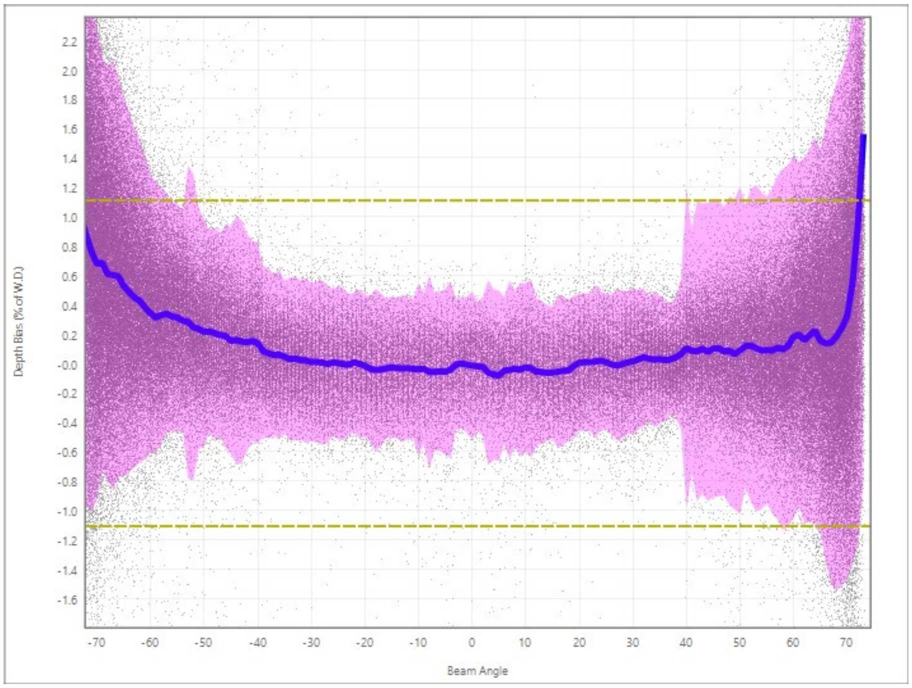



*Figure 24 - EM710 Deep Single Swath mode accuracy results as a percent of depth from the medium depth site (200 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations from the mean. The rapid change at +40 degrees is the port sector boundary.*

Very Deep and Extra Deep modes do not have Dual Swath capability and were thus only tested in Single Swath mode. The data were within 1% of water depth at two standard deviations to the mean difference, which equates to approximately 6 meters at this location.

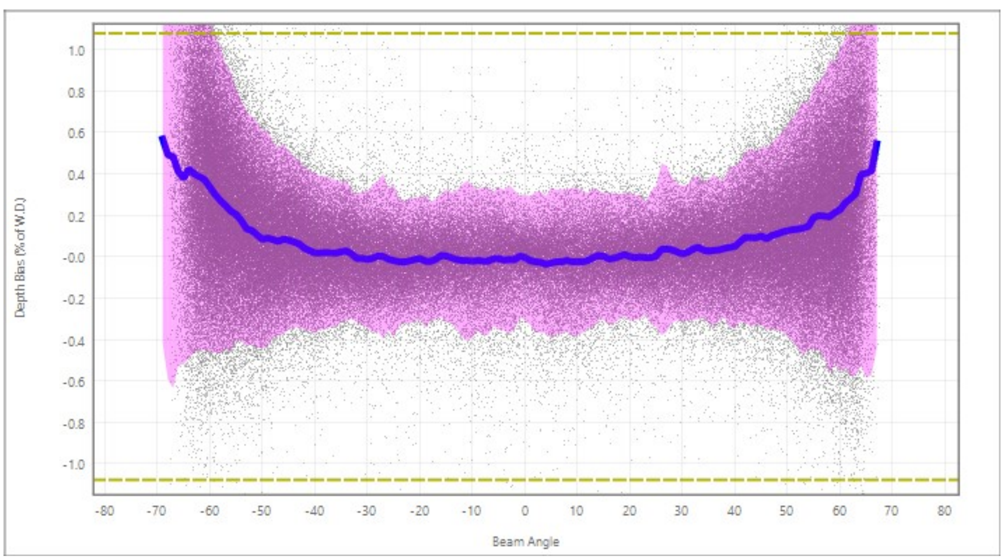



*Figure 25 - EM710 Very Deep mode accuracy results as a percent of depth from the deep site (~550 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations.*

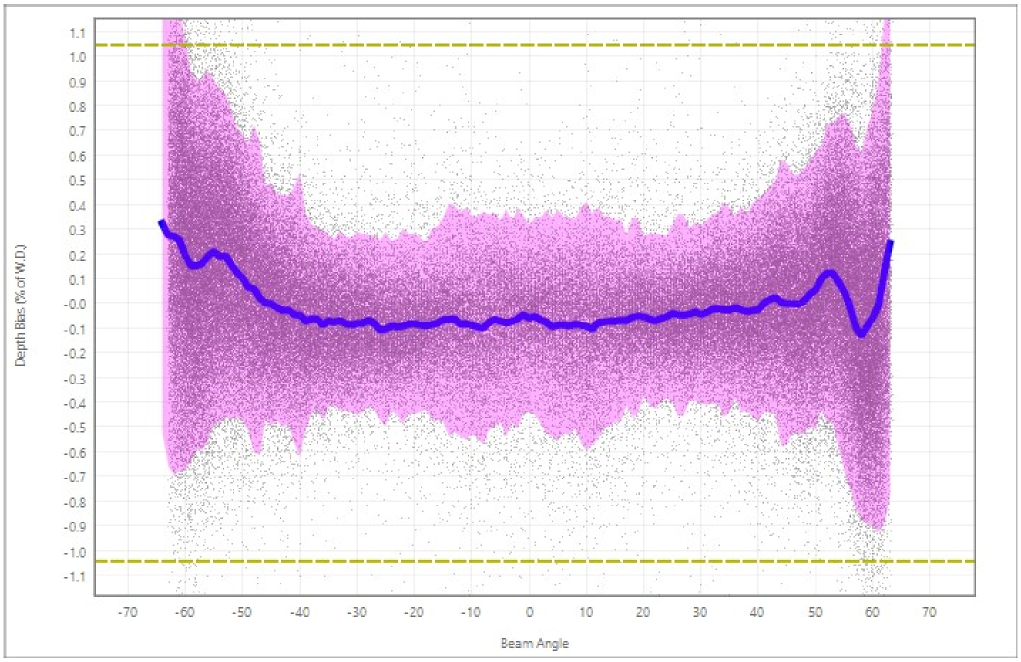



*Figure 26 - EM710 Extra Deep mode accuracy results as a percent of depth from the deep site (~550 meters). The blue line is the mean difference between the reference surface and this line. The pink region is 2 standard deviations.*

## 6.3 Noise floor testing

The purpose of noise testing is to assess sources of acoustic interference that may impact data quality. Also, establishing a baseline noise level provides for the opportunity to identify significant changes in the future. Noise floor testing was completed in several locations for different conditions. Tests were conducted using both the BIST RX Noise and RX Noise Spectrum functions in SIS as well as with water column in passive mode. Passive water column is shown as averaged along each beam as a time series of all pings. These data are then also averaged by each beam for each speed. Averaging by beam assumes that noise is at a consistent angle relative to the vertical, and in the case where noise is transducer relative the noise may be smeared across several angles as the vessel rolls. Averaging was completed in the linear domain after data outside of 3 standard deviations was removed from the time series. EM2040 analysis on passive water column is limited to the even pings because the odd pings did not present usable data due to a firmware problem. This problem was reported to Kongsberg and a fix is forthcoming. Only the main engine was used during testing.

A deep test area was chosen at the bottom of the extinction line in 2500 meters of water to minimize the effect of vessel noise reverberating off the seafloor. Both the EM2040 and EM710 were tested at this site. The weather was from the southwest at 15 – 20 knots with seas and swells at 2 – 3 feet. Tests were conducted both into and out of the weather.

Shallow water noise testing was undertaken in two locations. The EM710 shallow area was southwest of the Bow Mariner wreck in a depth of 70 meters and was only conducted going into the weather, which was from the southwest at 15 knots and 2 – 3 feet. EM2040 testing was also conducted in this location and under the same conditions. In addition, noise testing was also conducted for the EM2040 inside Chesapeake Bay during some of which the Doppler Speed log was also active.

These results are presented in the following echo sounder specific sections.

### EM2040 Noise Testing

BIST noise tests are governed by preset Kongsberg settings but passive water column is sensitive to user settings. The frequency mode is particularly important as it changes the echo sounder's sensitivity to noise at particular frequencies. Also, the maximum range setting changes the record length, with shorter record lengths opening gaps between water column records where burst noise might occur. In this case the deep water noise testing had a frequency setting of 200 kHz and a record length of 500 meters. The shallow water testing the in Chesapeake tested all frequencies but had a record time equivalent to a 50 meters range scale. The shallow water testing south of the Bow Mariner wreck had a frequency setting of 300 kHz and a record length of 100 meters.

The deep water BIST noise and noise spectrum tests collected into the seas are shown in Figure 27 and Figure 28. No significant change in background noise level with change in engine RPM was identified. Noise levels are generally low across all frequencies. This indicates that the system is limited by internal noise rather than flow noise. As noted in section 5.2, channel 52 appeared not to function correctly. There appears to be low background noise for all EM2040 frequencies as shown by the noise spectrum test.

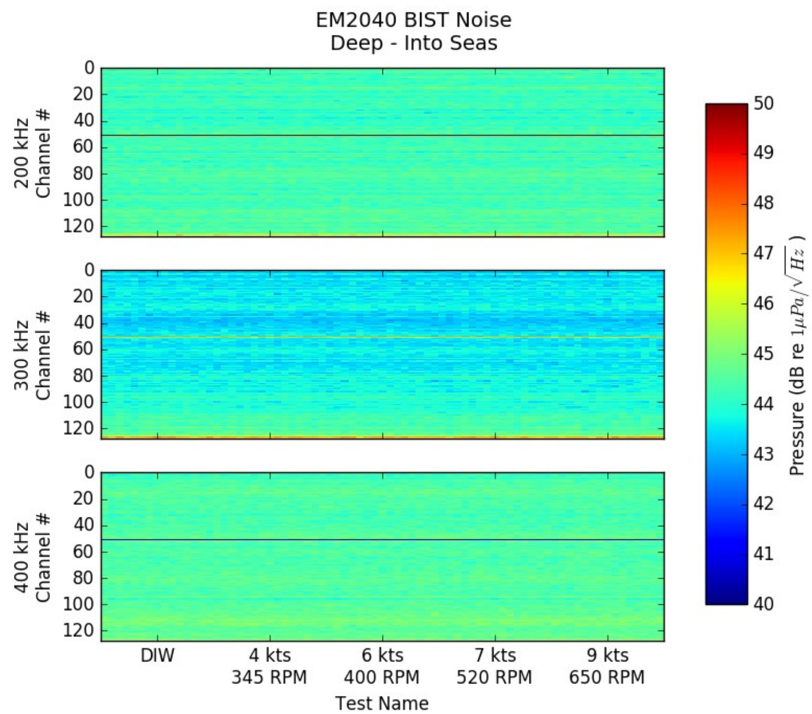



*Figure 27 - Deep water BIST Noise tests heading into the seas.*

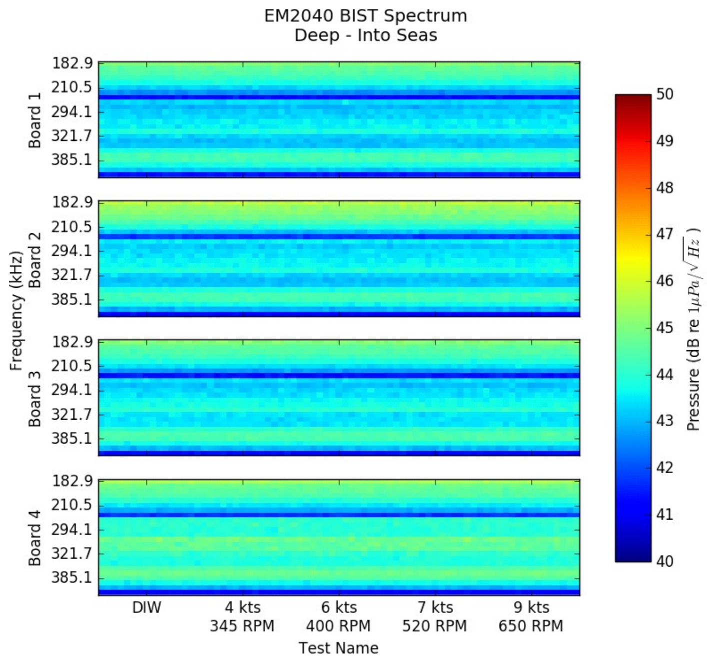



*Figure 28 - Deep water noise spectrum tests heading into the seas.*

Passive water column was also used to look at the beam formed deep water noise. Figure 29 shows the entire into seas dataset (even pings only) with little identifiable change. When dead in water (DIW) the noise was noticeably higher. Figure 30 shows the data as averaged by beam and by speed. In both figures there is coherent noise at boresight, and therefore transducer relative, and changes beam number as the vessel rolls. If this analysis were conducted by averaging through transducer relative angles rather than vertically stabilized angles (beam numbers) the coherent noise would be even more apparent in the speed relative plot. This coherent noise is likely electronic in origin.

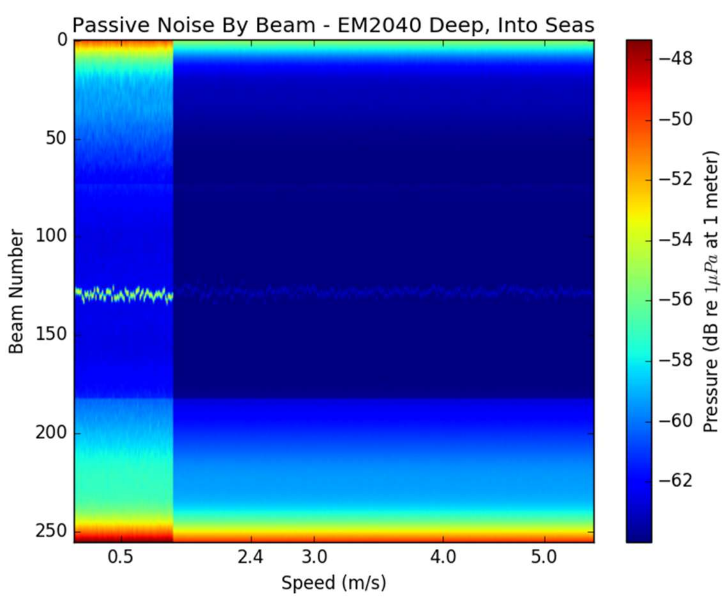



*Figure 29 - Deep water noise from passive water column heading into the seas. The EM2040 was in 200 kHz mode.*

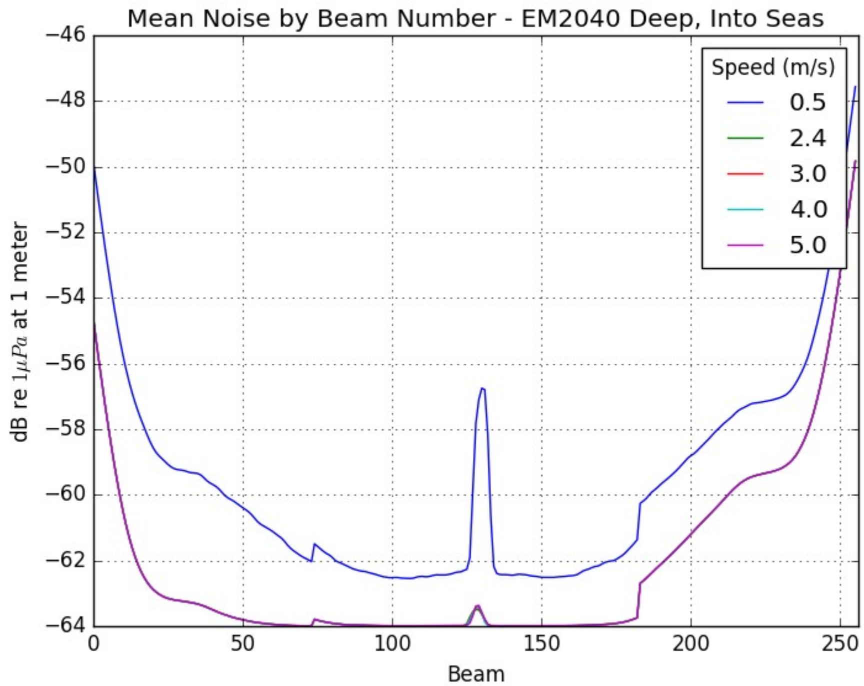



*Figure 30 - EM2040 deep water passive water column noise averaged by beam and for each speed heading into the seas. EM2040 frequency setting was 200 kHz.*

EM2040 deep water noise out of the seas is shown for comparison to the previous plots in Figure 31. The same data for not making way is used as for heading into the seas, thus the apparent difference between stopped and moving ahead in the previous plot is the same as between going into the seas and out of the seas, with heading down wind being a few dB higher.

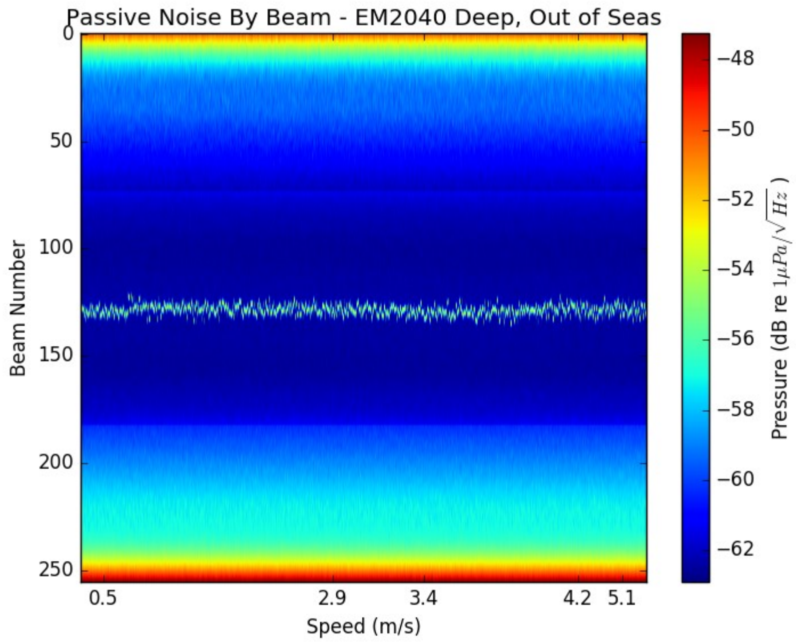



*Figure 31 - Deep water passive water column noise averaged by beam heading out of the seas.*

EM2040 shallow water BIST noise testing from 14 meters of water within Chesapeake Bay is presented in Figure 32. During the first set of tests the speed log was on and caused significant interference. At 500 RPM there is additional burst noise for the lower frequencies. Figure 33 shows how the EM2040 operates with low background noise across all frequencies with the same burst noise at 500 RPM. Again, the speed log was active during the first set of tests and was clearly interfering with all frequencies, although how it interfered depended on how the speed log transmit timed with the test.

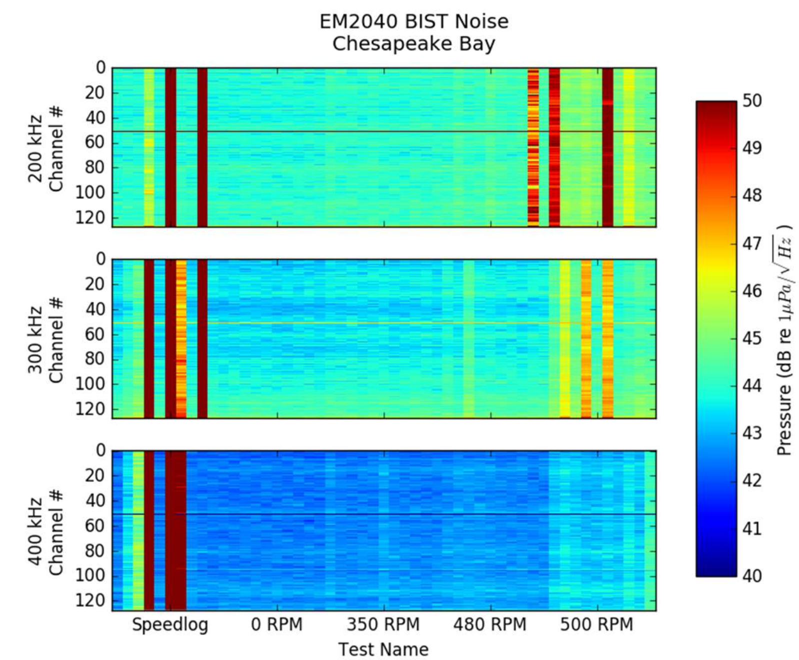



*Figure 32 – EM2040 RX Noise BIST Tests from 14 meters of water in Chesapeake Bay. High, intermittent levels are interference from the Doppler speed log.*

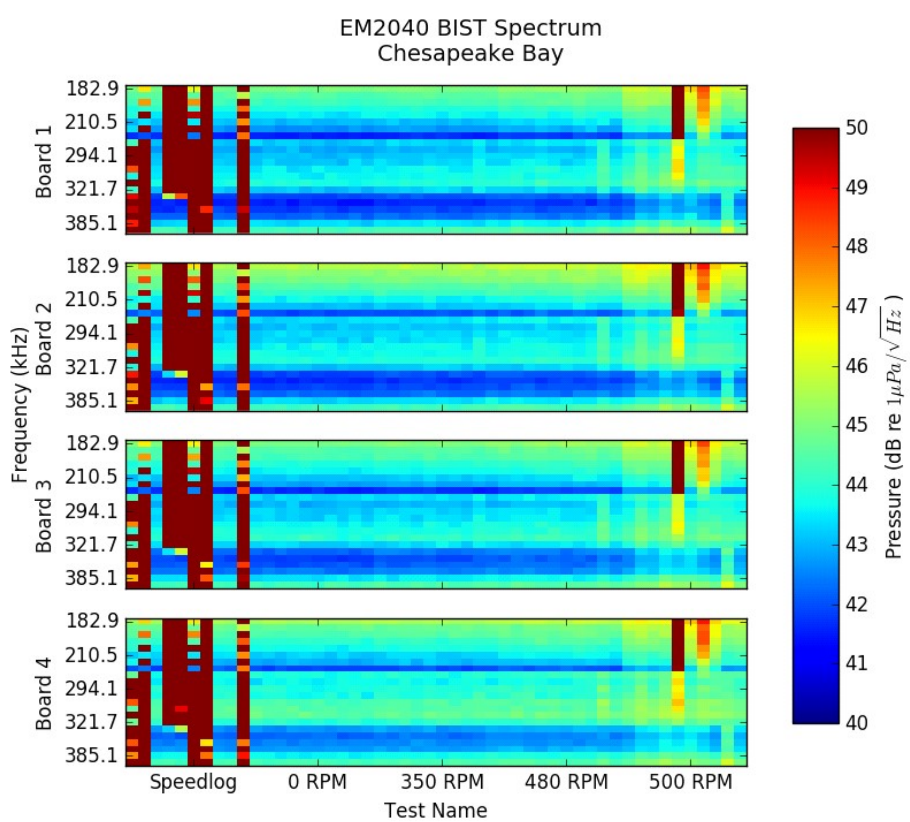



*Figure 33 - EM2040 RX Noise Spectrum test from 14 meters of water in Chesapeake Bay. High, intermittent levels are interference from the Doppler speed log.*

Passive water column showed consistent noise results across all frequencies for all speeds as show in Figure 34, Figure 35, and Figure 36. The speed log was secured for these tests. The nadir noise spike is most significant at 300 kHz, but also exists for all speeds for the other frequencies. A significant number of poor seafloor detections at nadir may result from this change in background noise in shallow water.

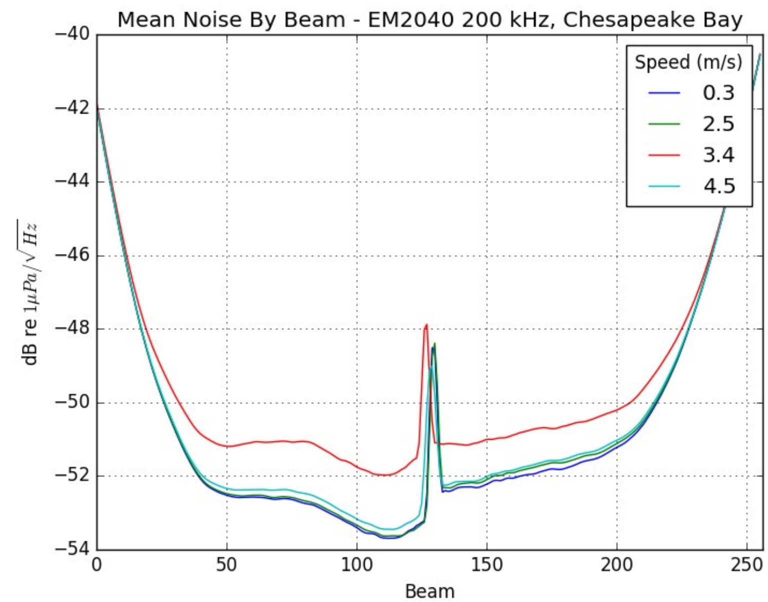



*Figure 34 – EM2040 passive water column noise for the 200 kHz mode as averaged by beam and for each speed in 14 meters of water.*

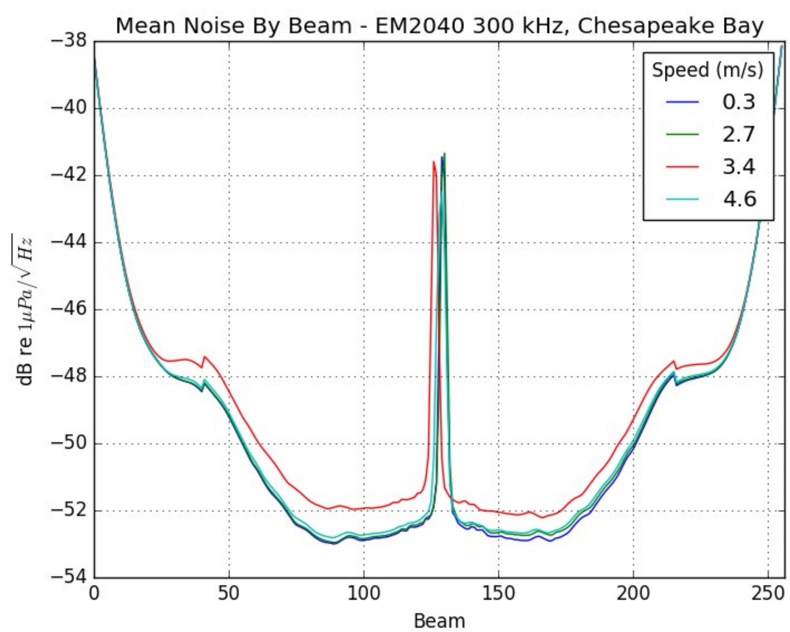



*Figure 35 - EM2040 passive water column noise for the 300 kHz mode as averaged by beam and for each speed in 14 meters of water.*

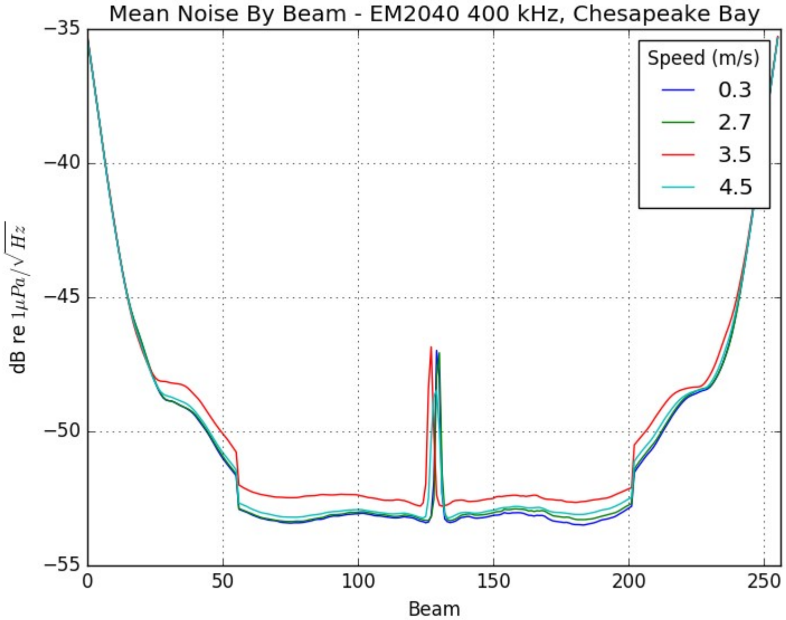



*Figure 36 - EM2040 passive water column noise for the 400 kHz mode as averaged by beam and for each speed in 14 meters of water.*

Figure 37 through Figure 40 are included to further stress the effects of the bridge speed log on the EM2040. The first two plots are for the 200 kHz mode, while the second two plots are for the 300 kHz mode. The beam averaged passive water column shows the change in average backscatter levels by ping. A single ping from each frequency setting is also shown to demonstrate the effect of the speed log in a real time view of the water column. The speed log should be secured during multibeam acquisition.

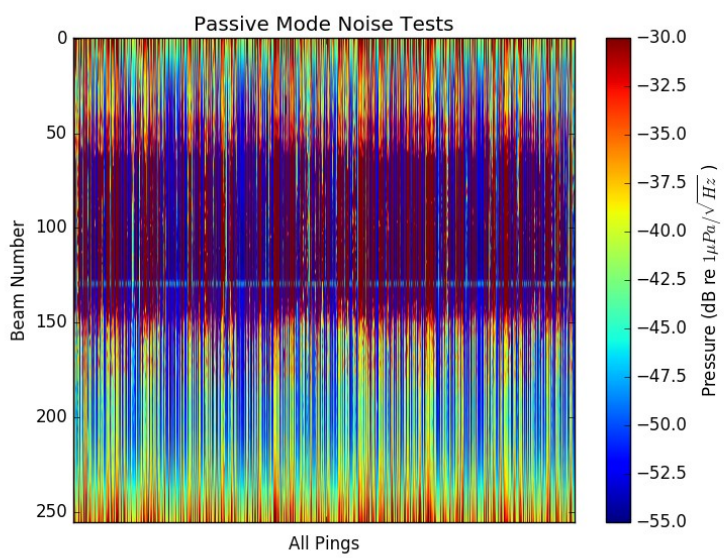



*Figure 37 - EM2040 passive water column noise for the 200 kHz mode as averaged with each beam in 14 meters of water. The speed log was active during this test.*

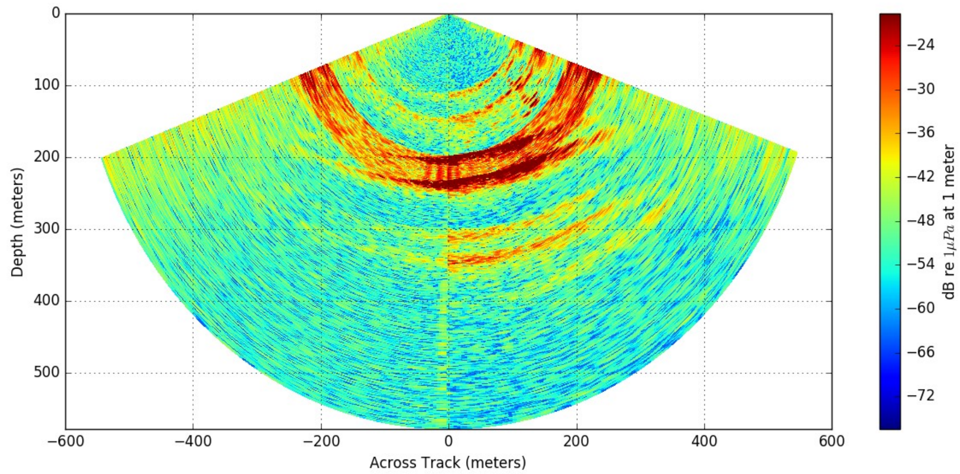



*Figure 38 – EM2040 passive water column from a single "ping" for 200 kHz mode. Speed log interference is evident.*

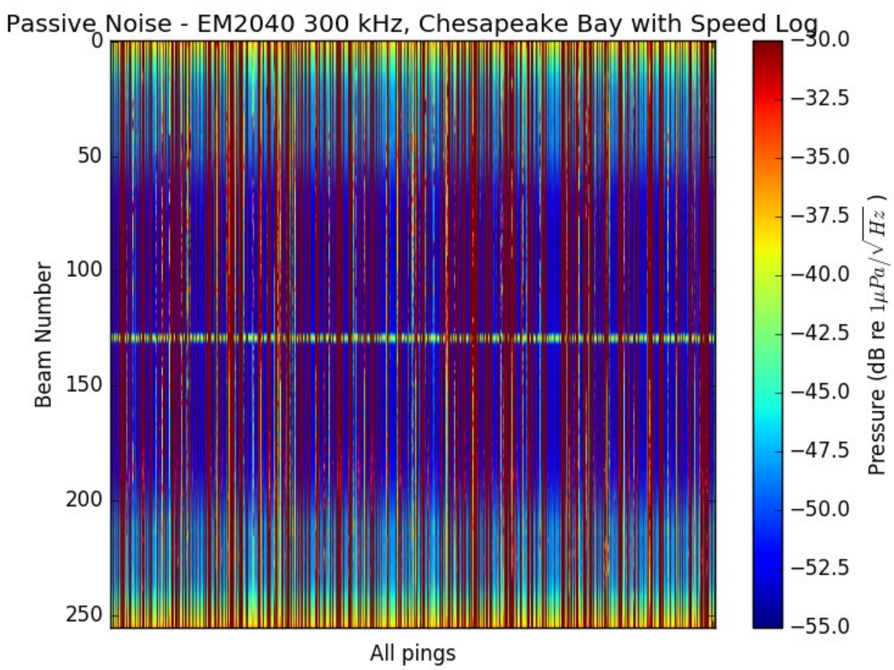



*Figure 39 - EM2040 passive water column noise for the 300 kHz mode as averaged with each beam in 14 meters of water. The speed log was active during this test.*

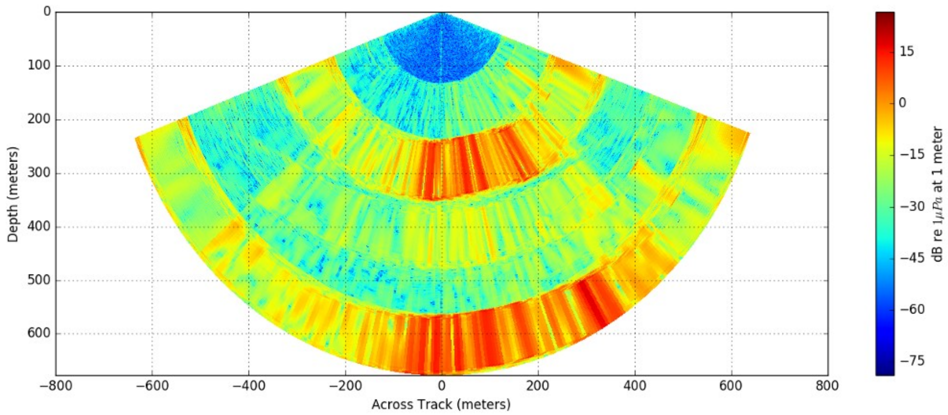



*Figure 40 - EM2040 passive water column from a single "ping" for 300 kHz mode. Speed log interference is evident.*

EM2040 noise testing was also conducted in approximately 70 meters of water as described previously. This dataset includes higher rates of speed than were collected in Chesapeake Bay and are thus presented here for completeness. No significant speed dependent change in noise is seen in the RX BIST Noise test as shown in Figure 41, although there does appear to be some additional burst noise at 10 knots. The RX BIST Spectrum Noise test also shows good background results across all speeds with the same burst noise at 10 knots. Background noise levels are higher in the Chesapeake data than for the deep water and 70 meter tests, indicating some effect from seafloor reverberation of vessel noise.

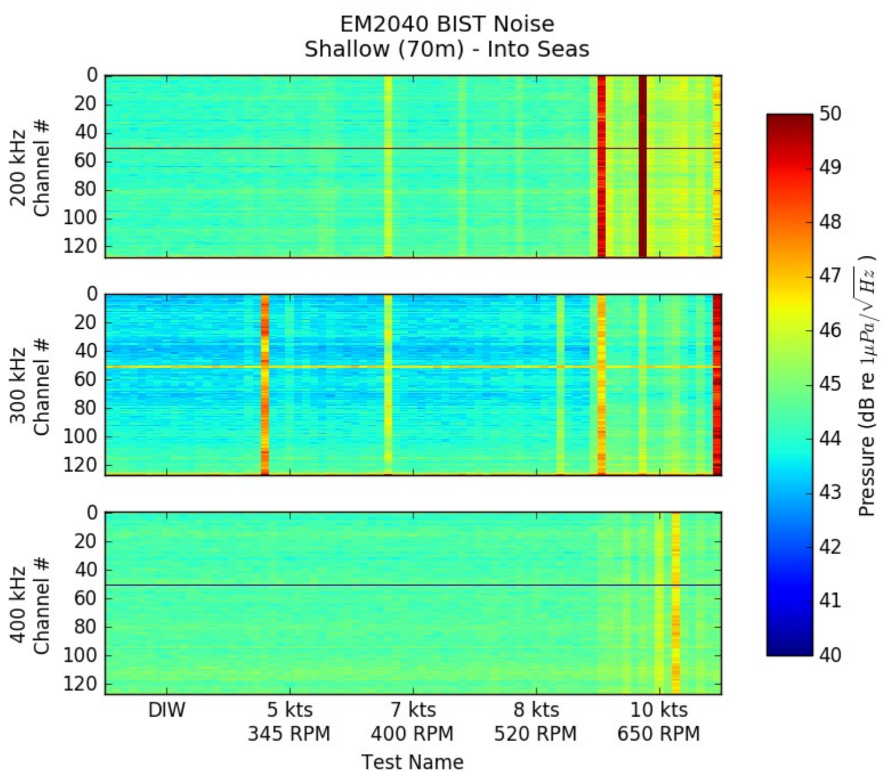



*Figure 41 - EM2040 RX Noise BIST Tests from 70 meters of water and into seas.*

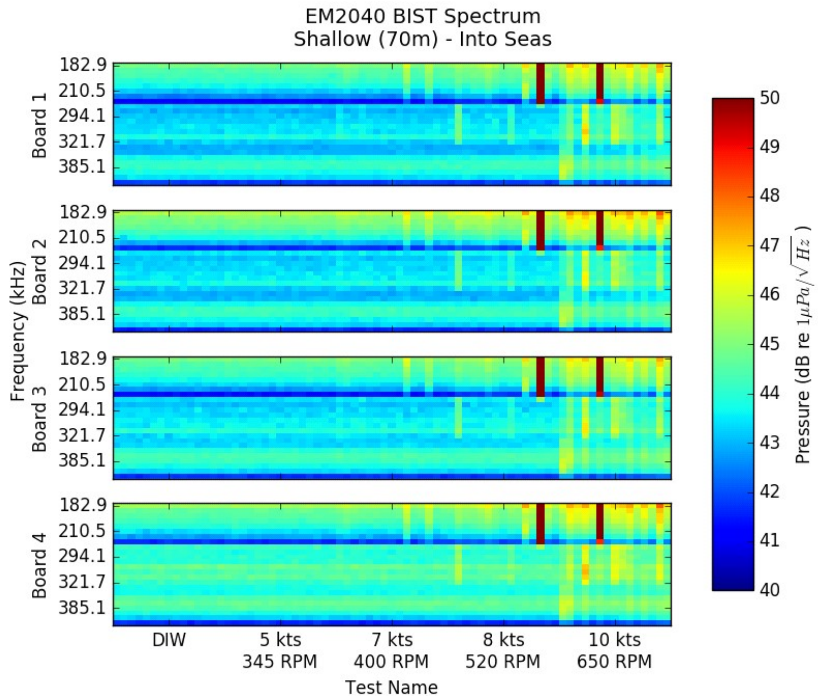



*Figure 42 - EM2040 RX Noise Spectrum test from 70 meters of water and heading into seas.*

For comparison to the Chesapeake Bay data, the passive water column data from the 70 meter areas is in Figure 43 and Figure 44. The background noise level is more on par with the deep water noise data, and the nadir noise spike is much lower for the slowest (DIW and 2.6 kts) and highest (5.6 kts) speeds.

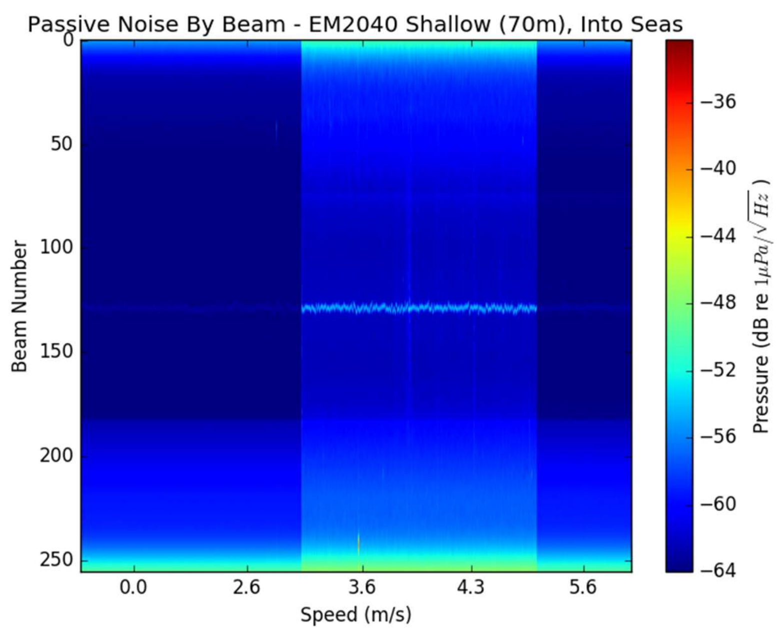



*Figure 43 – EM2040 300 kHz passive water column averaged by beam, heading into seas in 70 meters of water.*

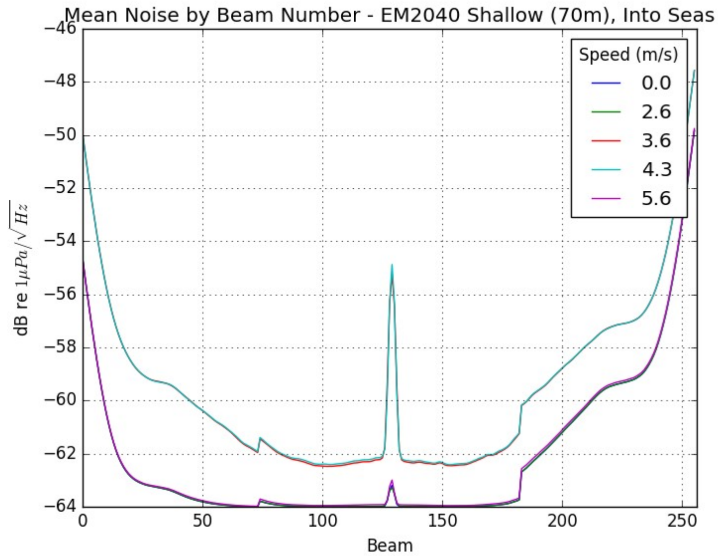



*Figure 44 – EM2040 passive water column in 70 meters of water averaged by beam and by speed while heading is into seas.*

These results do not indicate a specific recommended noise limited survey speed for the EM2040. Flow noise above the DIW level is not observable in either shallow or deep water. While the noise floor is higher in shallow water, it is not particularly dependent on speed and may or may not be due to the self-noise of the ship itself.

### EM710 Noise Testing

Passive water column testing for the EM710 was conducted in Shallow mode and with a 500 meter range. These tests were conducted at the same location and time as the deep water EM2040 noise tests.

Deep water noise testing did not demonstrate any speed dependence in the BIST noise tests for levels by channel or by frequency other than small burst noise at the highest speed (Figure 45, Figure 46). Both into and out of seas had similar results.

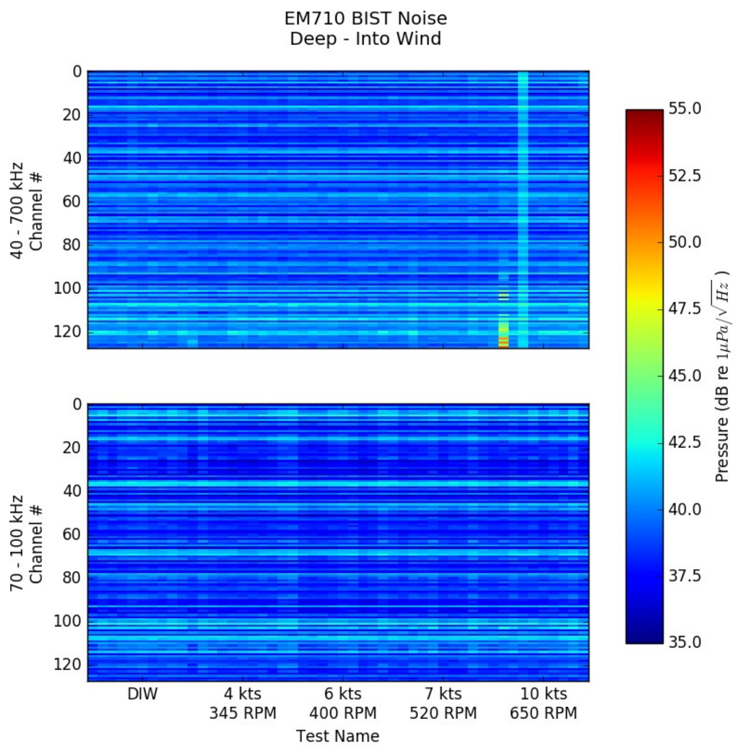



*Figure 45 - EM710 RX BIST Noise by speed and heading into seas in 2500 meters of water.*

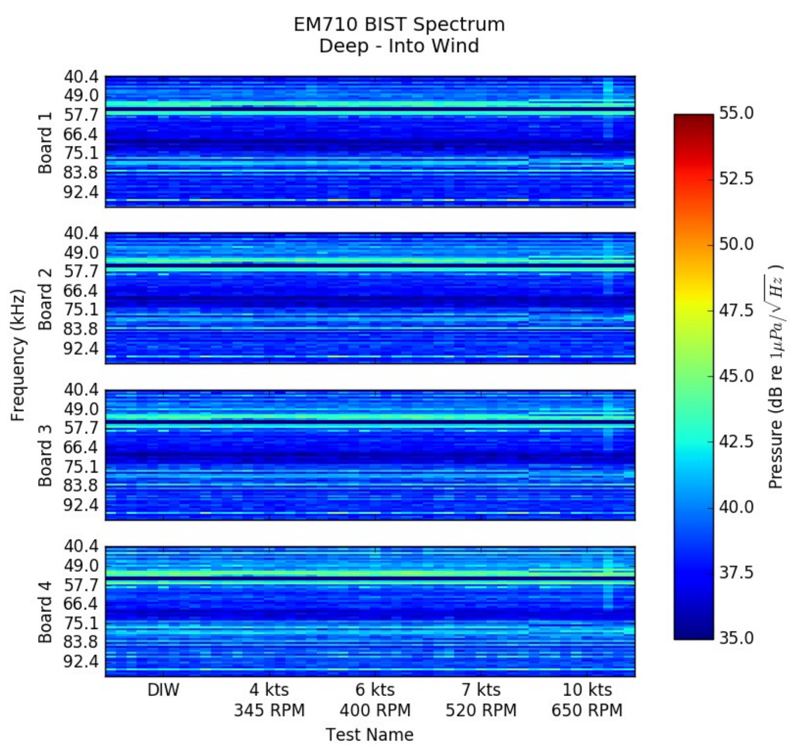



*Figure 46 – EM710 RX BIST Noise Spectrum by speed and heading into seas in 2500 meters of water.*

The beam formed passive water column showed more noise toward the outer swath at the highest speed, but the coherent noise at nadir remained at the same level (Figure *51*, Figure 52).

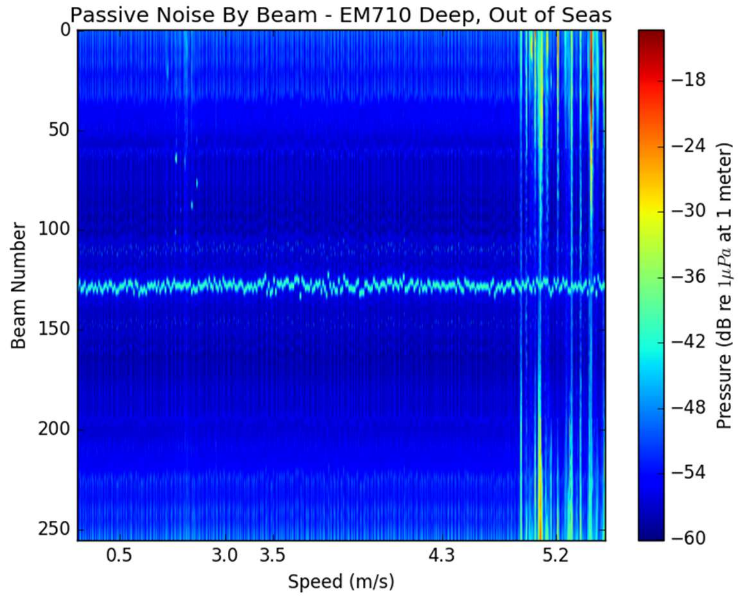



*Figure 47 - EM710 passive water column averaged by beam, heading into seas in 2500 meters of water.*

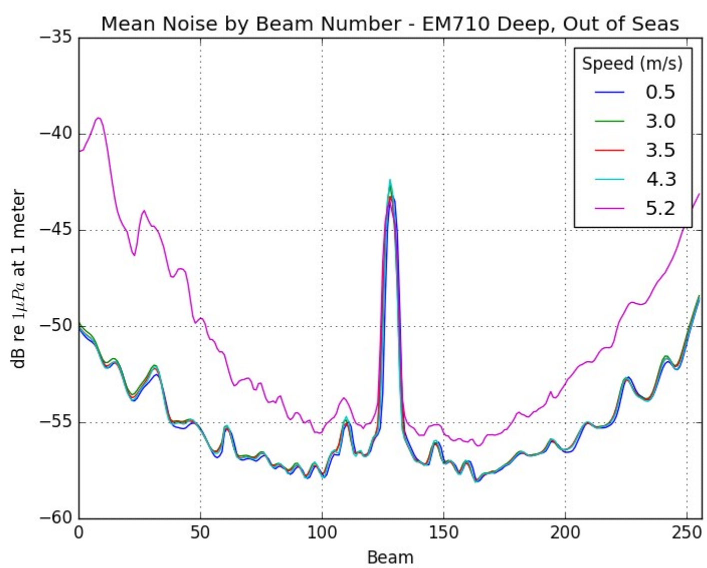



*Figure 48 - EM710 passive water column averaged by beam and by speed, heading into the seas in 2500 meters of water.*

Shallow water noise testing for the EM710 was conducted at the same location and time as the EM2040, and with the same settings as for the deep noise testing. BIST RX Noise and Noise Spectrum tests do show a speed dependence in this depth of water (70 meters), with higher background noise at higher speeds. Because this increase in levels was not observed in the deep area, this noise is likely not flow noise, but rather propulsion related self-noise propagating to the receiver via a bottom-bounce acoustic (e.g. downward radiated propeller noise, machinery noise through hull, etc.).

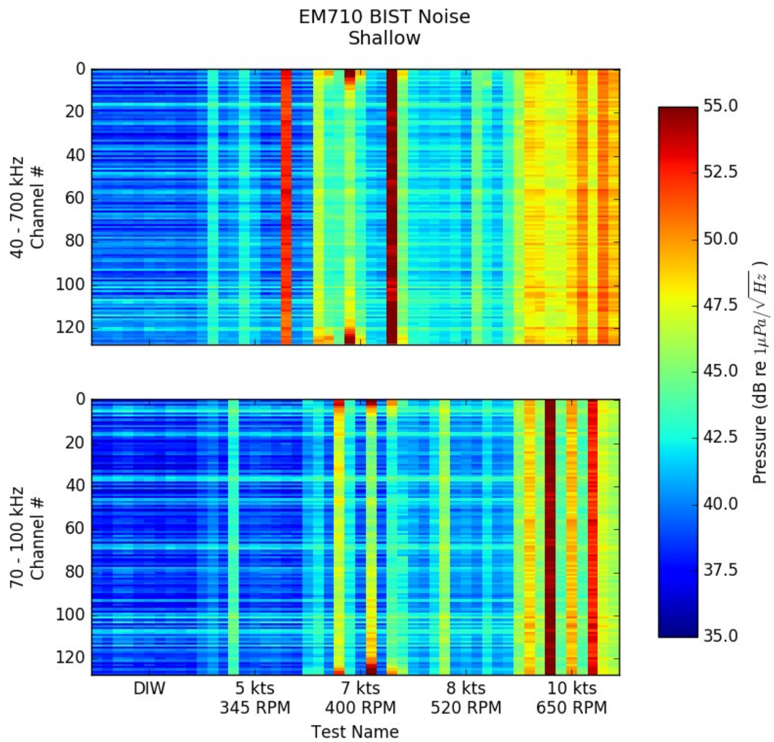



*Figure 49 – EM710 RX BIST Noise by speed and heading into seas in 70 meters of water.*

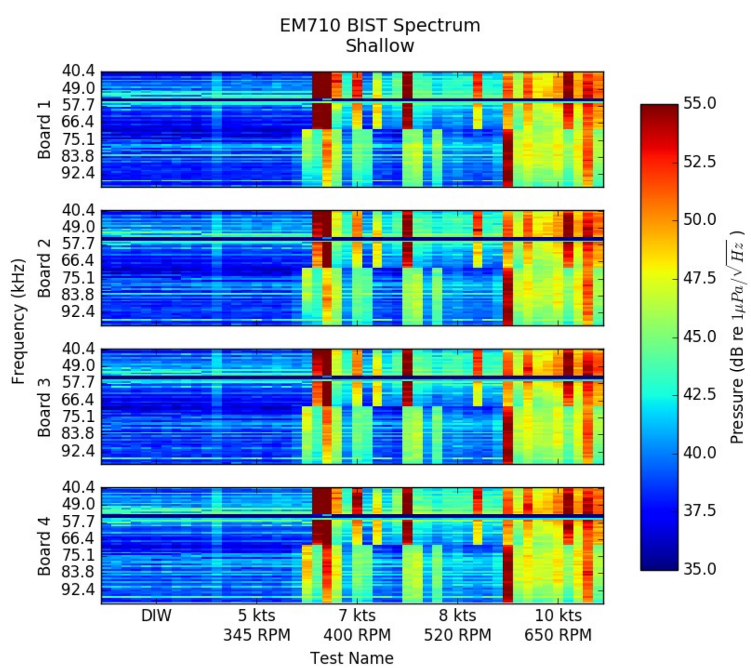



*Figure 50 – EM710 RX BIST Noise Spectrum by speed and heading into seas in 70 meters of water.*

Passive water column confirms the speed dependent noise observed in the BIST Noise tests in this water depth with the EM710. The change in background noise is most significant around nadir (as would be expected with an in-band bottom bounce noise source), which could potentially lead to noisier detections in this area of the swath at higher speeds and in shallow water. There is no clear noise floor limiting cutoff in acceptable survey speed.

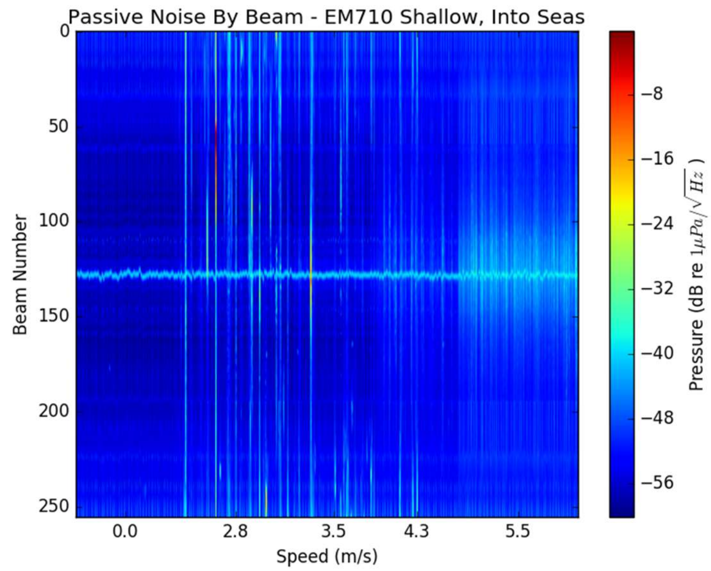



Figure *51* - EM710 passive water column averaged by beam, heading into seas in 70 meters of water.

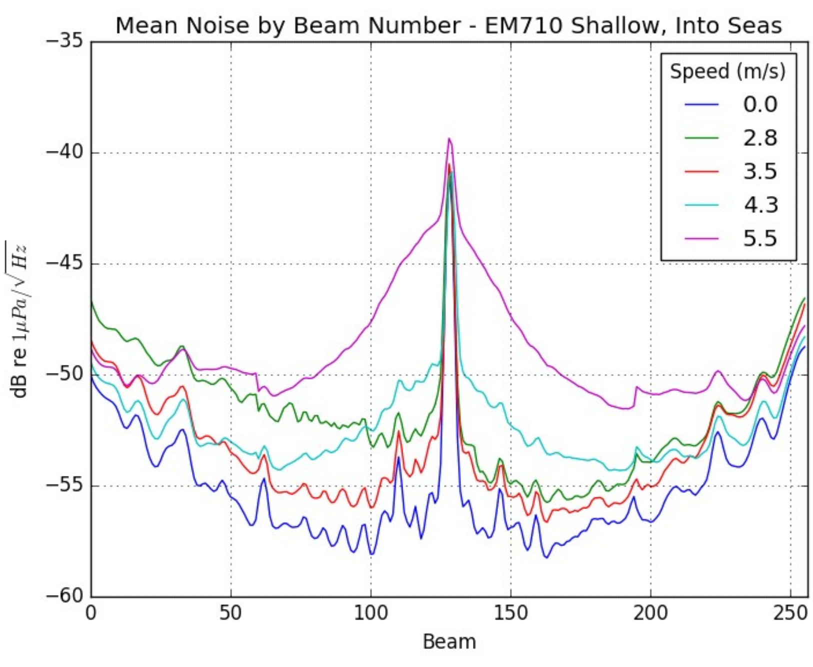



*Figure 52 – EM710 passive water column averaged by beam and by speed, heading into the seas in 70 meters of water.*

## 6.4 Target detection and recognition

### Observations of objects

The Bow Mariner wreck site contains many objects that are useful for testing a system's ability to detect and recognize an object. Three objects were chosen to be investigated with both the EM2040 and EM710. A debris field 1100 meters north of the wreck has an object that appears to stand 2.5 meters proud of the surrounding seafloor, which is 76 meters deep. This object appears to be approximately 5 meters wide. In addition, the Bow Mariner has several masts that were used as objects for investigation. The bow mast appears to stand 14 meters above the deck, which is at 55 meters of depth, with an unknown width. The aft mast, just forward of the bridge, appears to stand 9 meters from the deck, which is 55 meters from the surface, and be 4 meters wide.

The object detection performance of each multibeam was evaluated by counting the number of detections both on top and in total on the object above the seafloor. While this counting method is somewhat subjective (i.e. identifying what sounding is on the "top" of an object, which in this case was simply within the observed cluster within approximately 0.2 meters of the average depth on top of the feature), the number of points that would change from one count type to another should not have a meaningful impact on the conclusion. Figure 53 shows the object north of the wreck and illustrates how the points were counted. The EM2040 was in 300 kHz mode and the EM710 was in Very Shallow mode. The EM2040 was tested twice for each angle, once with the "Normal" detection mode and once with the "Min Depth" detection mode mentioned previously. No manual cleaning of soundings was completed for this analysis, and while points that could be considered noise were tracked, they were few enough that they did not present any meaningful conclusion for survey operations.

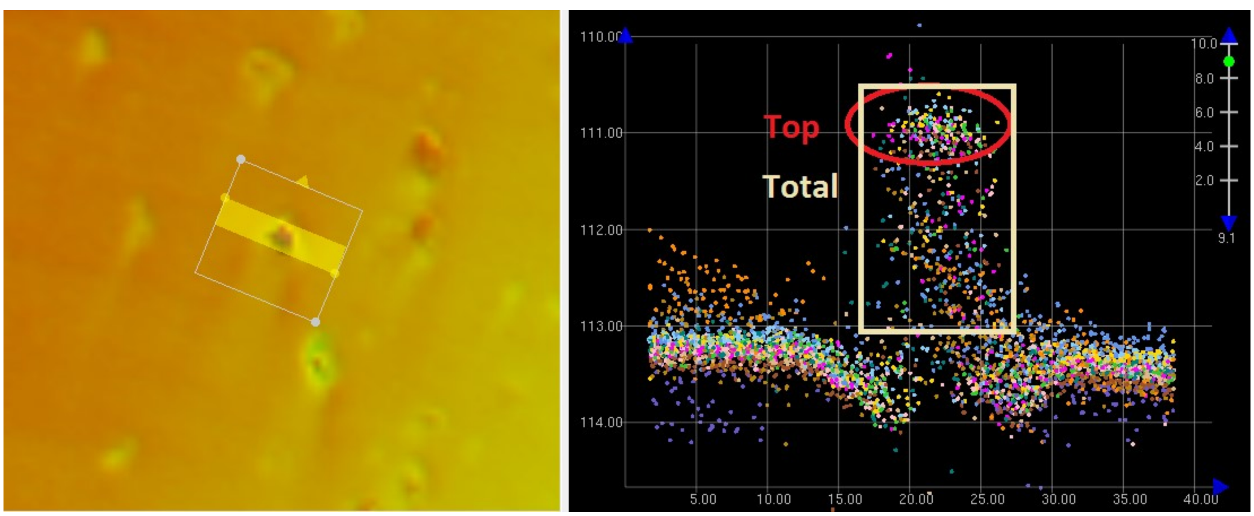



*Figure 53 – The seafloor object 1100 meters north of the Bow Mariner wreck used for object detection work. Depths are in meters from the ellipsoid.*

Lines were run at different offsets from the target to investigate the effect of across track angle on detections. The sounding counts for the EM2040 from swath angles between -20 and 71 degrees from nadir as shown in Figure 54.

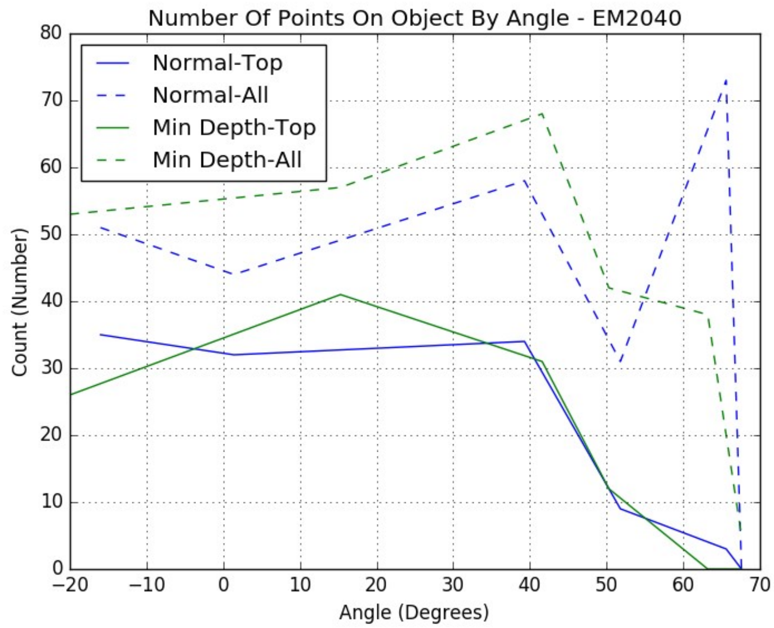



*Figure 54 – The number of detections on the object by the EM2040 by angle and for the Normal detection mode and Min Depth detection mode. "Top" is the number of detection on the top of the object, while "All" is for all points perceived to be anywhere on the object.*

The EM2040 appears to make more than half of its detections on the top of the seafloor object, making the representation of the least depth likely. Past 40 degrees, there are still numerous detection on the feature, thus making detection of the existence of a feature likely, but the number of detections on the top of the feature drops off quickly. Out to 65 degrees there are still detections on the object but the least depth is no longer reliably captured. The min-depth setting did not substantially increase the detections on the top of this object.

Using the same lines and methods, the sounding counts for the EM2040 from swath angles between -20 and 71 degrees from nadir as shown in Figure 55.

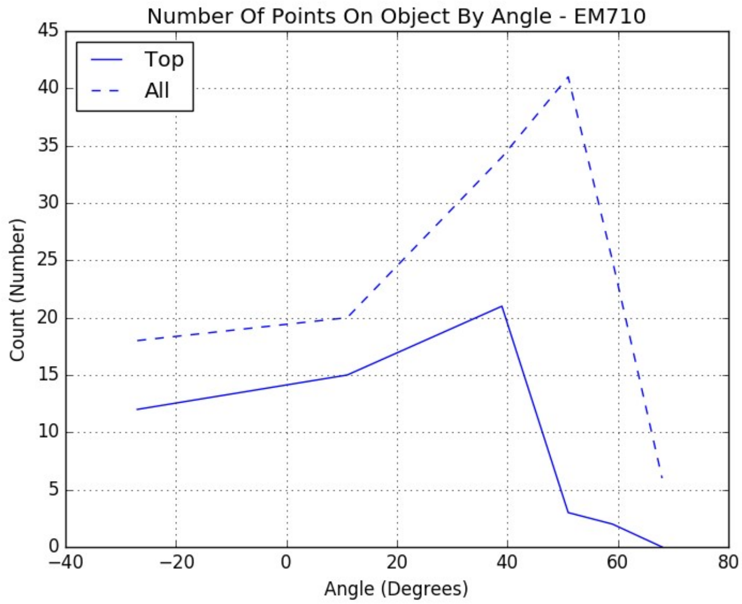



*Figure 55 - The number of detections on the object by the EM710 and by angle. "Top" is the number of detection on the top of the object, while "All" is for all points on the object.*

The EM710 does not have as many observations on the object, potentially in part due to a slightly smaller transmit beam width. Still, enough points are on the top of the object out to 40 degrees that the object will likely be recognized as its least depth if observed. Outside of 40 degrees the number of points on the top of the object drops off quickly, though the total soundings on the object are still high. Like the EM2040, detection of an object outside of 40 degrees is likely, but reliable detection of the least depth may not be.

The same analysis was completed for the bow mast on the Bow Mariner wreck (Figure 56). The number of these detections was not as consistent as for the seafloor object, so the results are presented in tabular form (Table 3).

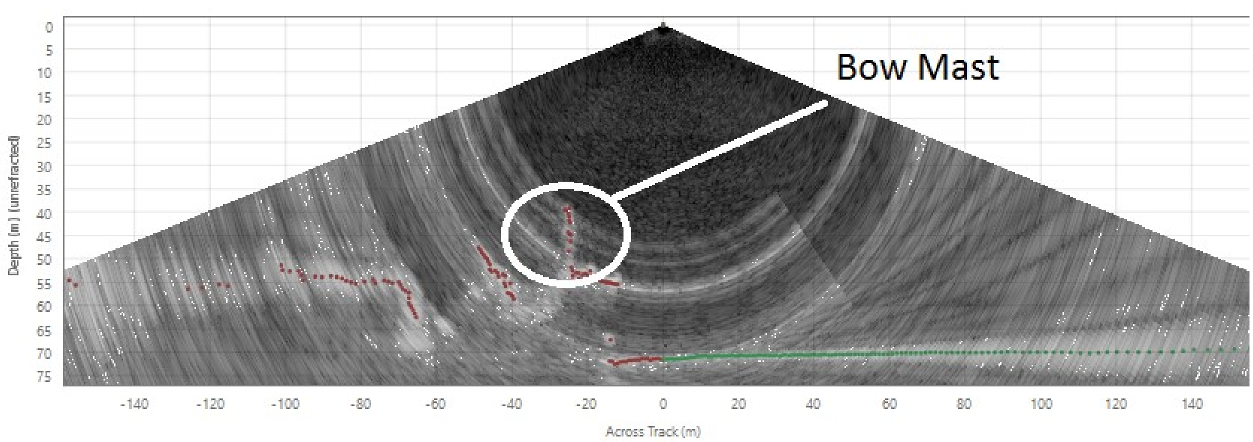



*Figure 56 – The bow mast feature as observed with the EM2040.*

*Table 3 – The number of EM2040 observations on the forward mast for the top of the object and total on the object by angle.*

| Angle (Degrees) | -30 | 22 | 71 |
|---|---|---|---|
| Top / Total, # of points, Normal Detection Mode | 0/3 | 0/8 | 0/0 |
| Top / Total, # of points, Min Depth Mode | 3/25 | 2/16 | 0/18 |

While the EM2040 does detect the forward mast with soundings reported on the structure, out of seven passes for each detection mode this object was only observed on three lines. Also, detections are only provided by the EM2040 on the upper part of the mast when the system is in "Mid Depth" detection mode. Qualitatively speaking, the object would only have been recognized if the system was in Min Depth mode as the total number of detections and detections on the top of the structure made the structure appear real rather than just noise.

The EM710 did not detect the bow mast on any of the survey lines.

This analysis was repeated for an aft mast near the bridge superstructure (Figure 57).

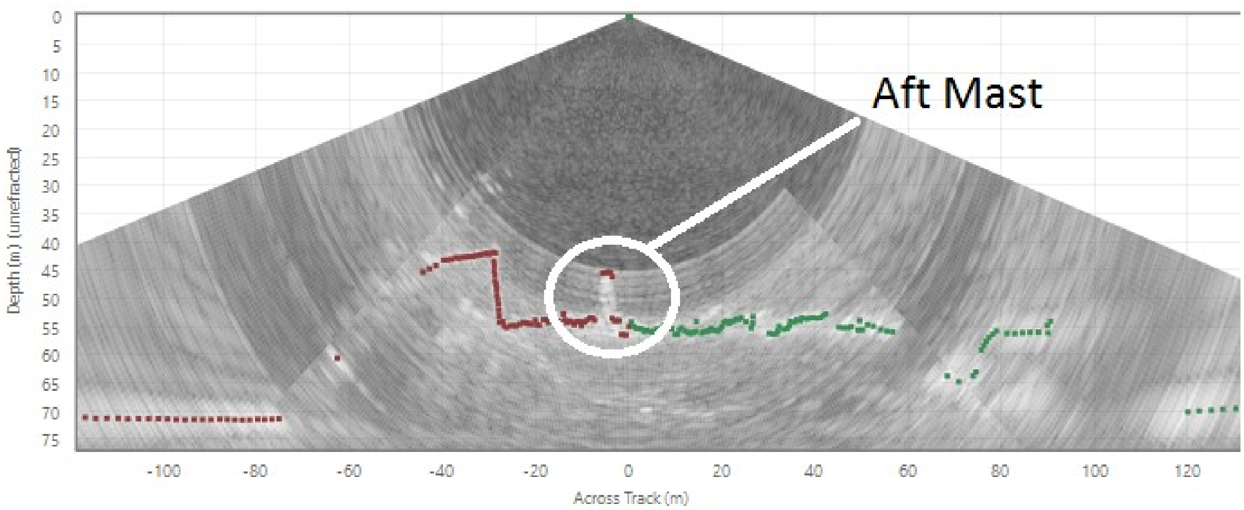



*Figure 57 – The aft mast feature as observed in a single line with the EM2040.*

*Table 4 - The number of EM2040 observations on the aft mast for the top of the object and total on the object by angle.*

| Angle (Degrees) | -8 | 35 | 45 | 58 |
|---|---|---|---|---|
| Top / Total, # of points, Normal Detection Mode | 0/3 | 0/0 | 0/8 | 0/4 |
| Top / Total, # of points, Min Depth Mode | 9/11 | 0/5 | 0/5 | 0/0 |

While the EM2040 does detect the aft mast with sounding reported on the structure, out of eight passes for each detection mode this object was only observed on three lines for each mode. Detections are only provided by the EM2040 on the upper part of the mast when the system is in "Mid Depth" detection mode. While this structure appears to have more volume than the forward mast, from published pictures of the vessel it is also appears composed of a truss network rather than presenting as a solid target. Also, this mast is observed within the side lobe reverberation of the bridge super structure due to the heading during survey, making it difficult to have a clean detection. Qualitatively speaking, the object would only have been recognized if the system was in Min Depth mode as the total number of detections and detections on the top of the structure made the structure appear real rather than just noise.

The EM710 did detect the aft mast with 4 soundings, but these would not have made the object recognizable as a significant structure.

Observations from the two targets on the wreck suggest that it helpful to run the EM2040 in Min Depth mode when conducting developments over a structure with vertical structures typical of anthropogenic features such as wrecks. The Normal detection mode appears to function just as well as Min Depth mode over natural seabed objects. Min Depth mode did not appear to increase the amount of noise added to the dataset over Normal mode, either over the wreck or over the flat seafloor. Even so, Min Depth mode is likely to produce detections on water column objects, such as fish schools, which are not desirable for hydrographic surveys. Unless further compelling evidence is found, we recommend that Min Depth mode only be used during development work.

As noted previously, the number of noisy points around objects was also tracked. A screen grabs of the Bow Mariner is show in Figure 58 to illustrate the point. In general, there is very little noise.

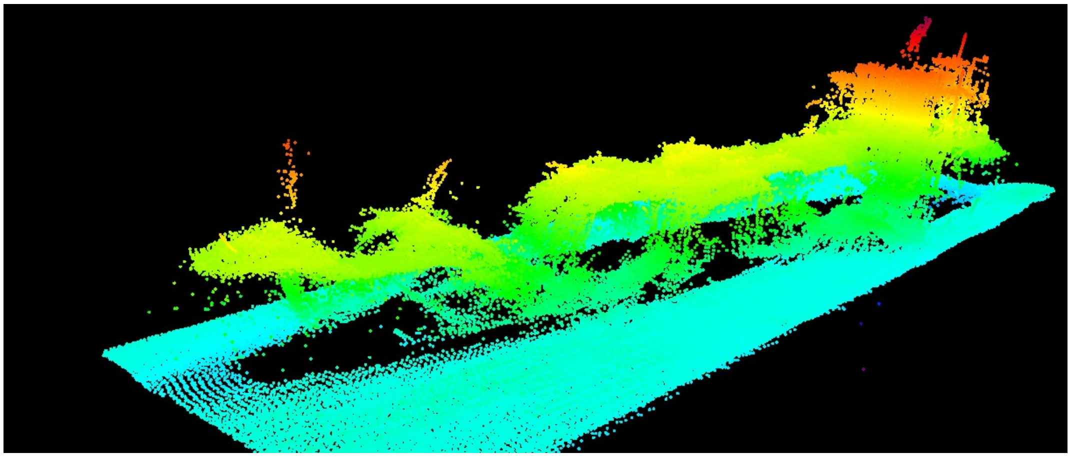


*Figure 58 – EM2040 data from the wreck without cleaning.*

It is worth pointing out, however, that when Kongsberg data is imported into Caris a significant number of rejected points may be included (Figure 59). Kongsberg systems will produce interpolated or extrapolated data but flag them as such. Caris imports this data and flags it as rejected by the echo sounder. It is important not to reaccept these points.

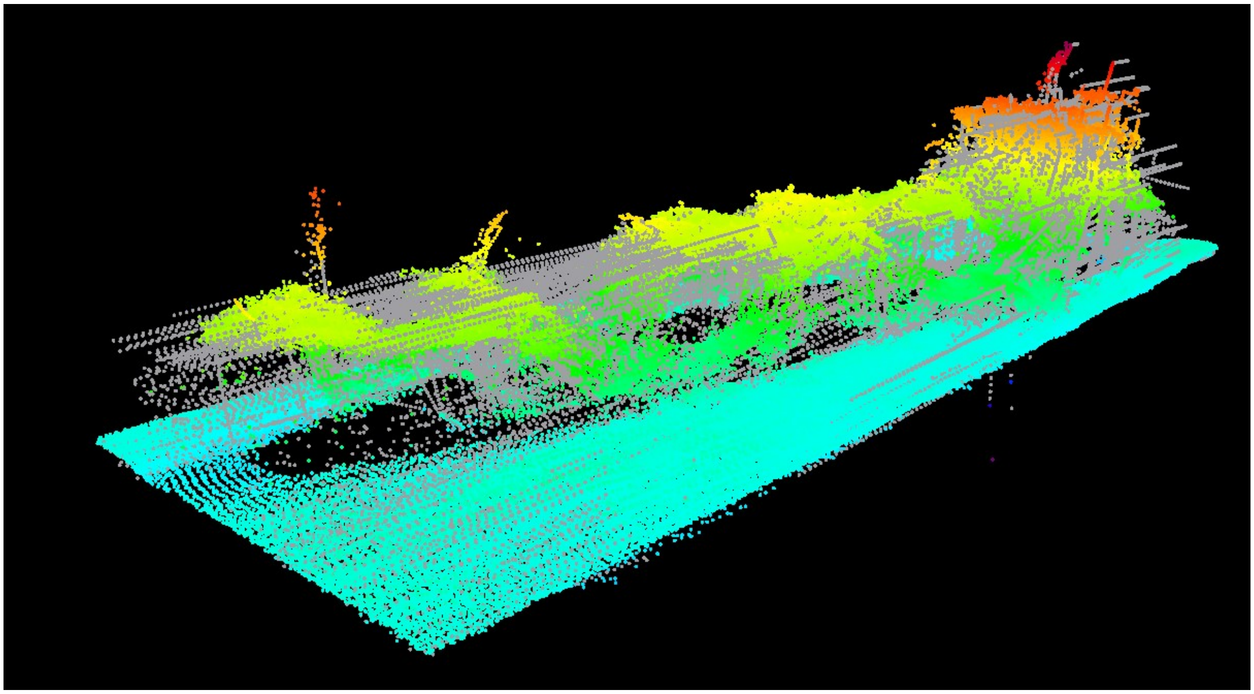


*Figure 59 – EM2040 data from the wreck, showing data rejected, interpolated, or extrapolated by the MBES as grey.*

### Systematic Survey System Artifacts

During the acceptance cruise an outer beam bathymetric artifact was observed. This artifact was particularly noticeable over flat seafloors, and could not be correlated to motion. This artifact was also confounded by internal waves during targeted testing, further confusing its source. An example of the artifact can be found in Figure 60 and Figure 61.

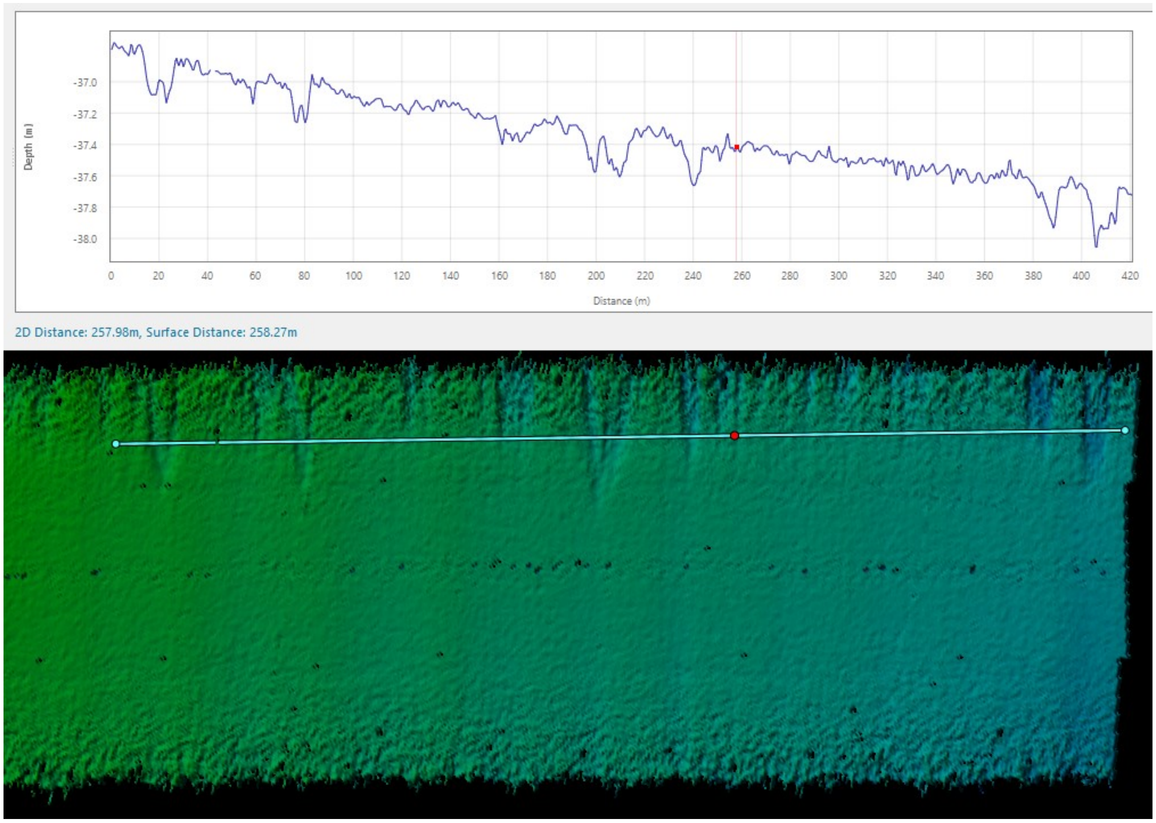



*Figure 60 – The leeward artifact as observed in a single line of EM2040 data. The top plot is a profile view of the swath, while the bottom is an overhead view of the line along which the profile was taken. Heading was toward the left.*

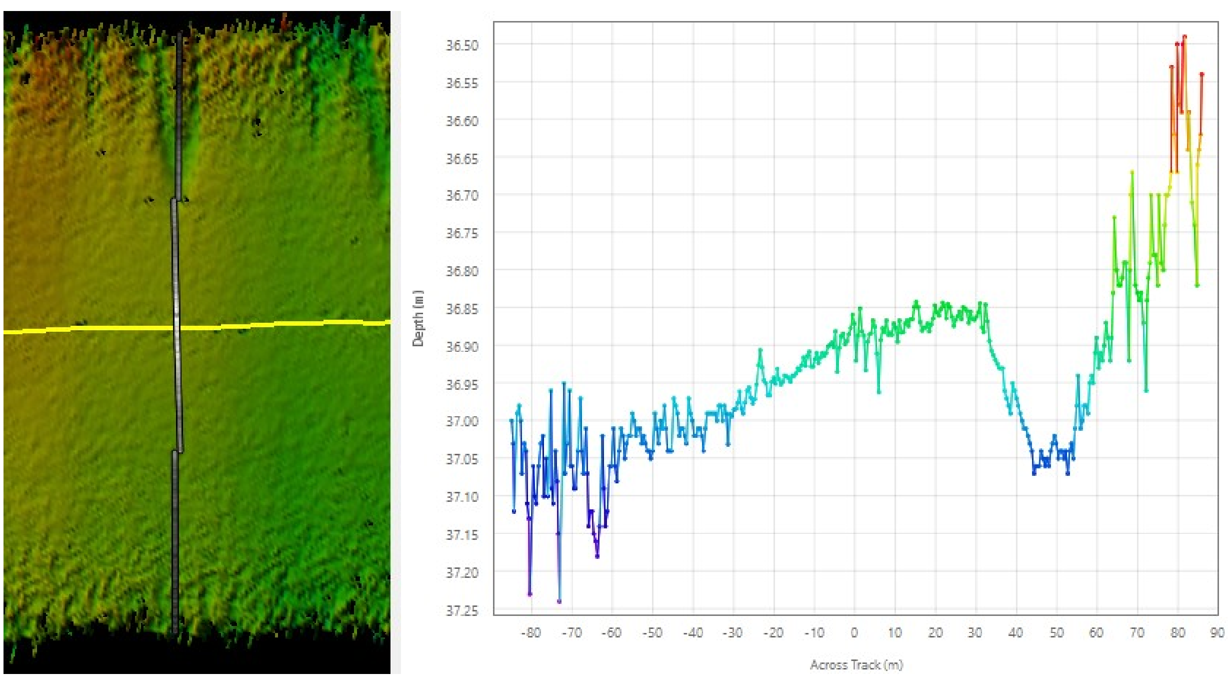



*Figure 61 – The leeward artifact as observed in a single ping of EM2040 data. Left is the swath cross section, right is the single swath profile colored by depth.*

This artifact occurs over multiple pings, apparently moving toward nadir and subsequently moving outward again.  This artifact appears predominantly on the leeward side of the vessel, although can also exist on both sides when the weather is not abeam.  After extended review by Kongberg and HSTB, and thanks to additional data collected by ship personnel post-acceptance cruise, this artifact is believed to be due to some upstream source of micro bubbles.  The most likely sources of these bubbles could be one or more of three structures forward of the transducers, including a line cutter bar just forward of the transducer mount, a small appendage on the bow, or the bow thruster.  The bubbles are not directly detected in the water column data or noise testing, but appear to be changing the sound speed of the water.  Conceptually, as a cloud of microbubbles passes past the echo sounder, the beams are refracted away from nadir causing those beams affected to appear deeper.  While this theory has yet to be proven, there is currently no other explanation that accounts for the relative weather direction dependence of this artifact.

Previous to the installation of the new survey echo sounders bubble sweep down was considered and discussed with field experts [5].  Because it was important to the U.S. Navy to conduct quality hydrographic surveys, previous testing of bubble sweep down of the *Thomas Jefferson* hull (as the USNS *LittleHales*) had been completed.  Of the three likely sources of bubbles forward of the transducers, two were added since ownership of the vessel passed to NOAA, the cutter bar installed with the gondola, and the bow thruster.  The cutter bar has been removed during a subsequent yard period, but no new testing for the artifact has been completed.  If the artifact still persists, the bow thruster remains the likely candidate for the source of the bubbles since it was added by NOAA.  Because abatement of bubbles with the bow thruster as the source will likely require significant modifications to the ship, plans for imaging the bubble cloud with cameras or imaging sonars has been discussed should the artifact still be present.

The standing recommendation is for the ship to collect EM2040 data in single sector mode until the bathymetric artifact is resolved.  This restricts coverage to 45° on either side, reducing the likelihood that the artifact will be present in the collected bathymetry.  While this configuration is not ideal, and a frustrating situation for a brand new survey system, the ship regularly conducts side scan surveys where the multibeam is primarily used to fill in at nadir and gather general bathymetry.  In the short term limiting the data to only the good part of the swath will help avoid introducing questionable data into the survey workflow.  This problem clearly needs to be resolved such that Coast Survey can use these new tools to their full potential.

## 6.5 Sonar Performance Parameters

The useable swath width as a function of depth is important to survey planning, survey quality, and survey efficiency.  Both the EM2040 and EM710 were tested by running the systems up and down a slope and plotting the usable swath as a function of depth.  The usable swath width is defined by the outermost good beam on each side of the swath as reported by the multibeam.  Because seafloor type has a strong impact on the returned signal level, the achievable swath width does depend on the seafloor type. Ideally, we would run these tests over a steady slope of homogeneous (and known) sediment type.  It is worth noting, that the identified outermost good beam can still contain noise or an incorrect depth as it has only been designated “good” by the system.

### EM2040 Extinction Test

The EM2040 was tested for all frequency modes but left to automatically select the pulse length. The planned location for EM2040 extinction testing contained significant amounts of fishing gear, thus a different testing location was selected on the fly. While the improvised location for extinction testing had a suitable maximum depth, the minimum depth did not allow for all modes to clearly demonstrate how the system would perform in shallow water without considerable additional transit time. Also, this location appeared to have a significant change in the seafloor type (Figure 62) which caused an abnormal inflection in the extinction curve at approximately 200 meters (Figure 63).

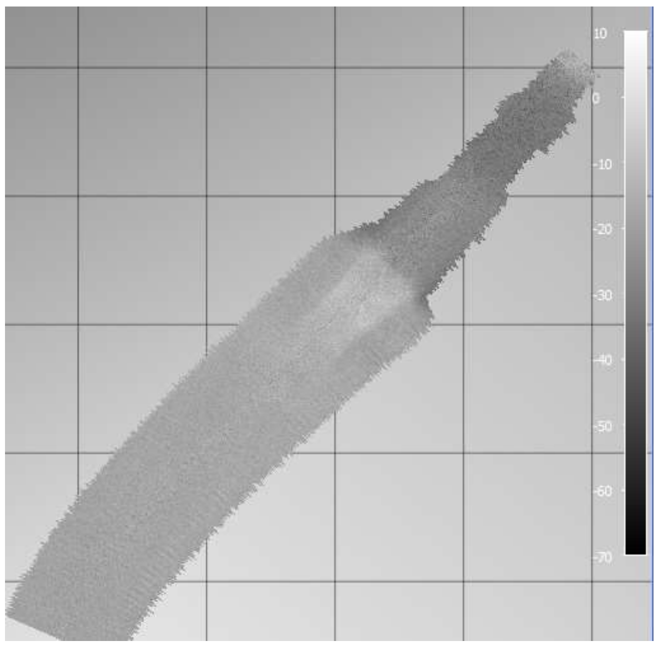



*Figure 62 - A line in 300 kHz mode from the first extinction site demonstrating the change in backscatter as seen in QPS FMGT.*

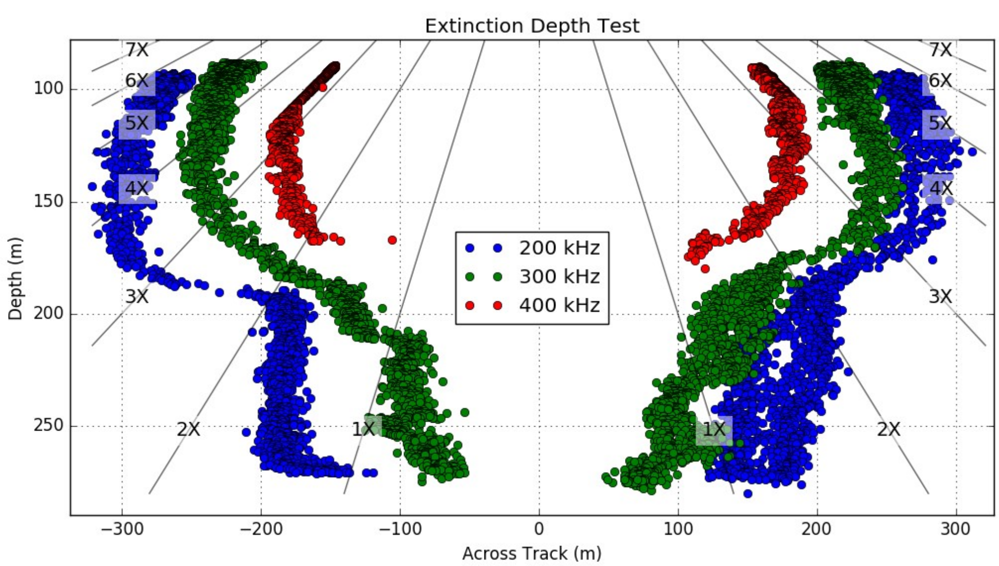



*Figure 63 – EM2040 extinction data at the improvised location. The pulse length was selected by the system automatically. Shown are the outermost good detections on each side of the swath.*

To supplement this test, the EM2040 was also run during the EM710 extinction test. 200 kHz data was collected while steaming down the slope, and 300 kHz data was collected while steaming up the slope (Figure 64). These results have a smoother transition between depths than the improvised location as would be expected for a consistent seafloor type over the test area.

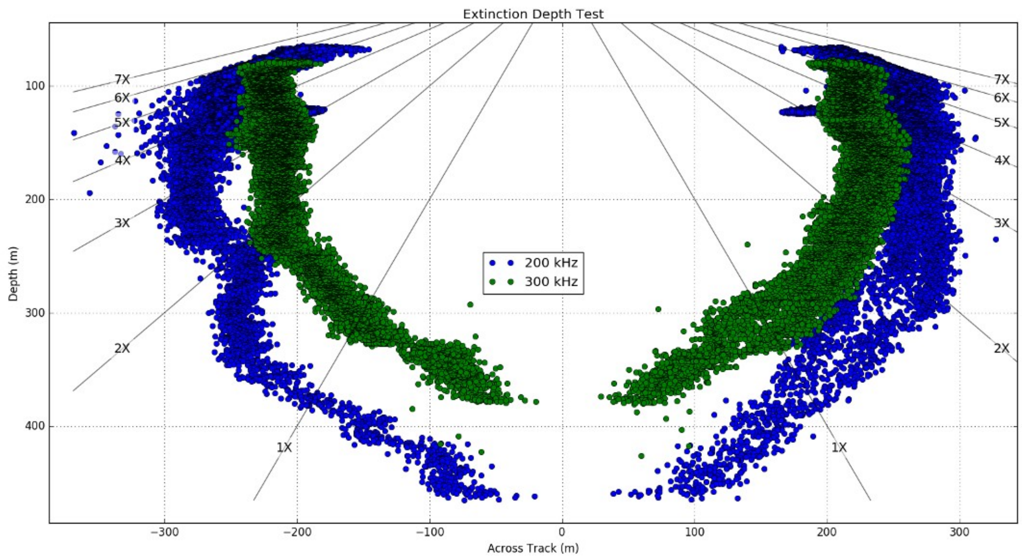



*Figure 64 – EM2040 extinction testing on the EM710 extinction test line. The pulse length was selected by the system automatically. Shown are the outermost good detections on each side of the swath.*

For all three frequency modes the *Thomas Jefferson* EM2040 appears to meet the Kongsberg specified swath width by depth within the uncertainty of variability due to seafloor type. In general, the performance follows the predicted extinction curve for a cold ocean with a sandy seafloor. The variability of the results with apparent seafloor type is expected, and worth remembering when planning surveys using these plots. Results will vary based on the seafloor conditions encountered in a particular area.

### EM710 MKII Extinction Test

The EM710 extinction line ran from 75 meters down to 2500 meters of depth along the southern side of Hudson Canyon. This appears to be a good location for this test as the slope has minimal interruptions from canyons between the applicable depths that would interfere with the results. The EM710 was left to select the mode automatically, and was only tested in the 40 – 100 kHz mode. The other modes (e.g. 40 kHz mode, 50 kHz mode, and 70-100 kHz mode) largely use sub-modes of the 40 – 100 kHz modes, and *Thomas Jefferson* is expected to have no need to operate in these specific modes.

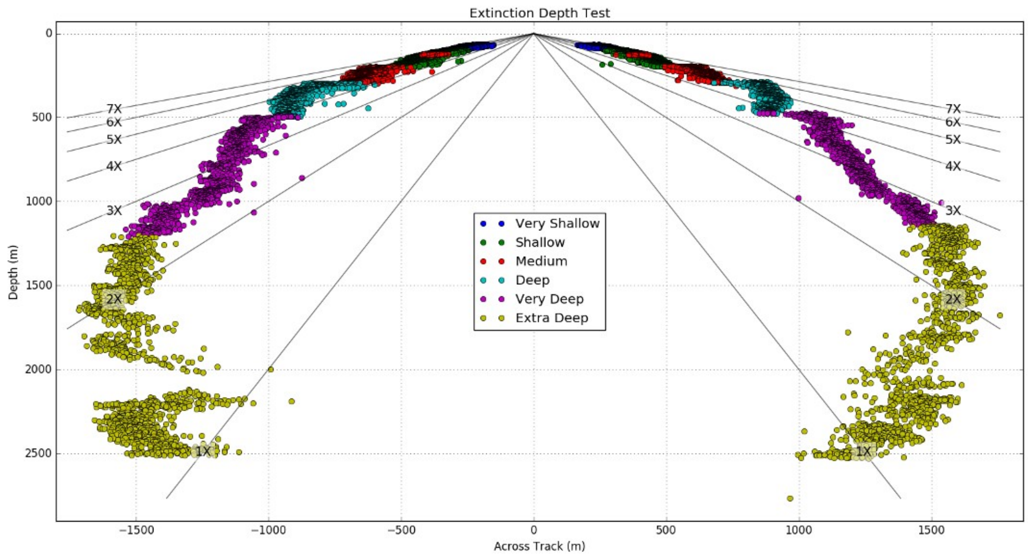



*Figure 65 – EM710 extinction test results. The mode setting was selected automatically. Shown are the outermost good detections on each side of the swath.*

The EM710 MKII follows the predicted seafloor performance predicted for a cold ocean with a rocky seafloor. While no seafloor samples were taken during acceptance testing, it is unlikely that the seafloor was rocky during the duration of the line. Assuming the seafloor was not rocky, the EM710 likely exceeds the predicted Kongsberg performance swath width by depth performance.

## 6.6 Backscatter quality assessment

Kongsberg multibeam echo sounders adjust the recorded seafloor backscatter to account for beam pattern effects. The real time backscatter can be improved and made more useful by updating this adjustment with values post-installation. To accomplish this, some form of backscatter calibration needs to be completed to update these parameters. Currently these parameters can be adjusted on the EM710 but not on the EM2040. The BSCorr.txt file stored on the TRU contains the power level used for each sector of each mode as well as the relative receiver sensitivity by angle. Previous methods adjusted the sensitivity settings to account for the differences in backscatter levels between sectors and modes. For *Thomas Jefferson* only the power levels were adjusted to align the sectors.

Two types of backscatter calibrations were used during this cruise for the EM710 modes mostly likely to be used aboard *Thomas Jefferson*. Time was not taken to calibrate the lesser modes less likely to be used (e.g. 40 kHz, 50 kHz , 70 – 100 kHz) since the available time for calibration was not clear when in the proper locations. The same method for collecting calibration data as was used in the past, consisting of a single line in each direction for each mode over a flat seafloor, was used in this case as well. Because of limited time for analysis, implementation, and testing, only the power offset was used to normalize between sectors. This approach improved the real time backscatter considerably (Figure 66) while also simplifying the changes needed to the Kongsberg BSCorr file. Modifying the angle sensitivities can be laborious if undertaken by angle as has been done previously.

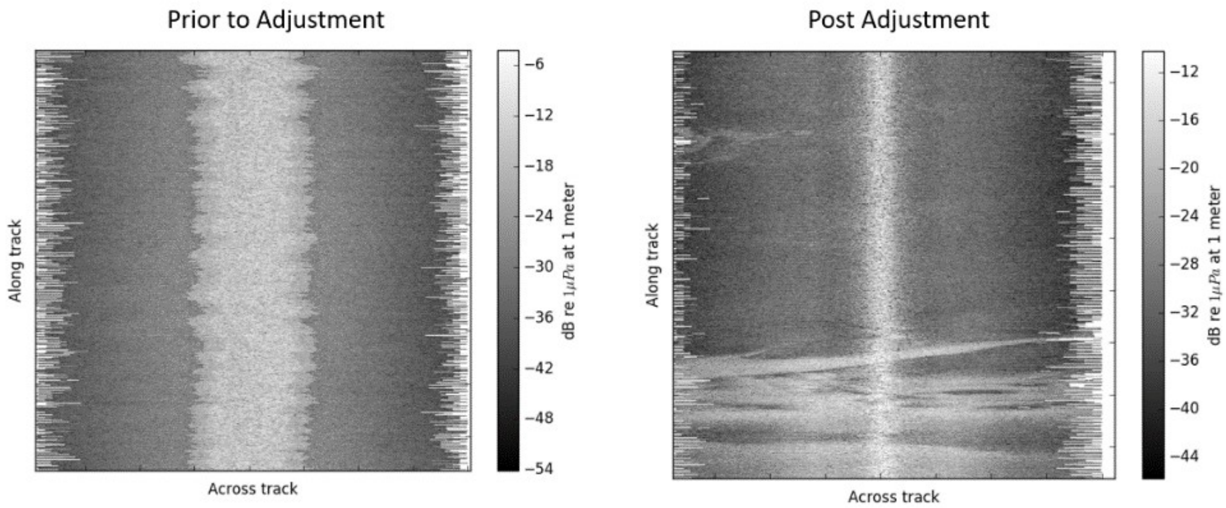



*Figure 66 – Seafloor backscatter with the EM710 before the BSCorr.txt file was adjusted (left) and after adjustment (right).*

The relative changes made to the port and starboard sectors to match the backscatter produced by the center sector are listed by mode in the summary in Table 5. The center sector was left with the default power value. The units for the sector power are not defined but are assumed to be some form of transmit power in dB.

*Table 5 – The updates made to the default EM710 BSCorr sector power.*

| | Port Adjustment (KM Units) | Starboard Adjustment (KM Units) |
|---|---|---|
| Very Shallow – Dual Swath 1 | +8.0 | +8.0 |
| Very Shallow – Dual Swath 2 | +8.0 | +8.0 |
| Shallow – Dual Swath 1 | +7.5 | +8.0 |
| Shallow – Dual Swath 2 | +9.5 | +9.5 |
| Medium – Dual Swath 1 | +6.0 | +7.0 |
| Medium – Dual Swath 2 | +7.0 | +8.0 |

Data were also collected for a secondary approach which was developed Dr. Anand Hiroji. These lines were run to determine the full transmit beam pattern as described in [6]. Dr. Hiroji continuous work on these data and will provided results to the ship when complete.

While the EM2040 backscatter was not calibrated, observation of the backscatter showed an unexplained artifact when operating in 200 kHz mode (Figure 67). This artifact appears as an area of depressed backscatter on the port side at 30 degrees from nadir, roughly where sector boundaries would be expected if 200 kHz had three sectors. The 200 kHz mode only has two sectors.

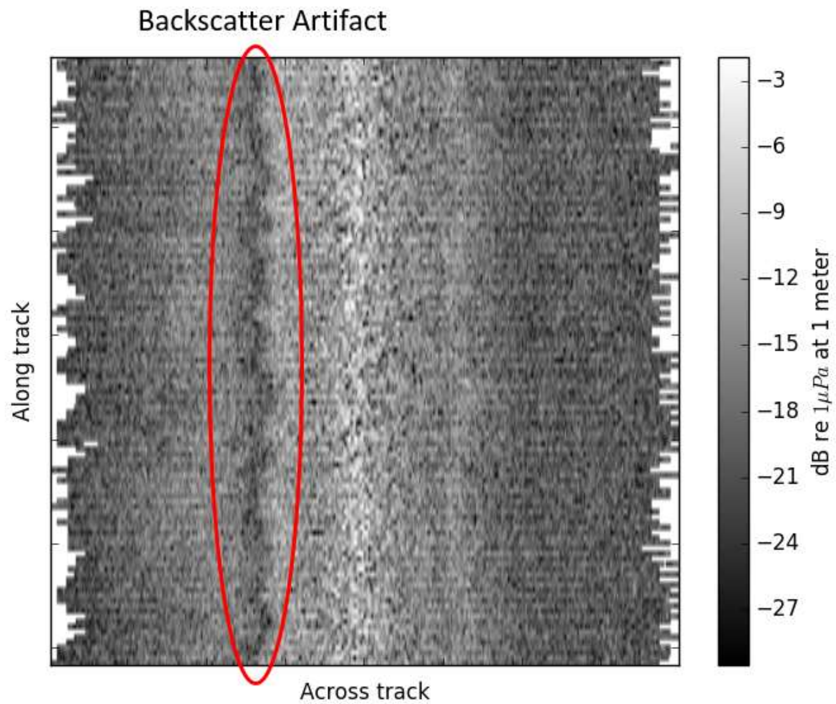



*Figure 67 – The EM2040 200 kHz mode backscatter artifact.*

Kongsberg identified changes to the installation that may remove or improve this artifact. Kongsberg was primarily concerned that the EM2040 transmitter was not protruding down from the cover plate sufficiently, and that the faring compound around the transducer may be interfering with transmission. In addition, they also recommended changing the amount of paint coating the transducers. They considered the amount of paint evident on the transducers from pictures excessive, and felt that it could also be impeding performance. These recommended adjustments were accomplished during a follow on shipyard period but testing to quantify any improvement has not yet been completed.

# 7 Data Workflow Integration

## 7.1 Test application of post processed correctors

Post processing for the *Thomas Jefferson* acceptance cruise was conducted in Caris HIPS versions 9.1 and Qimera 1.3. With previous Kongsberg installations in the NOAA fleet ([1], [2] ,[7]), the reference point was set as the transmitter of the echo sounder, and the output of the inertial navigation system was valid at this point. This configuration was chosen in those cases to eliminate the lever arm calculations in Caris, which had a known deficiency in applying delayed heave corrections for Kongsberg systems. For the *Thomas Jefferson*, we elected to make the IMU the reference point (see section 4.1.1 for more information). This choice was primarily motivated by the fact that with *two* multibeam systems and a single positioning system we could not have the reference point uniquely at *each* transmitter. This configuration is also common NOAA practice (for non-Kongsberg systems) and seems to be more intuitive to many. As tested in [3], the former lever arm related delayed heave errors seem to have been resolved in Caris 9.1, however survey work following the cruise in shallow water with extreme pitch revealed a residual pitch-related error and pointed to a complication with the desired HIPS workflow. A discussion of the current HIPS logic for Kongsberg systems as well as how the current version of SIS effects the workflow is provided here for clarity.

Kongsberg systems provide the end user with both a processed sounding solution and the angle-range raw data. Because the processed solution requires the application of many adjustments to the real time data, some of the data, such as the motion data, can be modified from its raw state. Most notable to this discussion, the motion data is modified according to the lever arms and angles provided in the Installation and Test Parameters Sensor Setup tab (Figure 68). Roll, pitch and heading have the values applied from the Attitude fields (commonly the patch test values), and heave is modified to account for the induced heave due the lever arms from the motion sensor to the transducers when the vessel is pitching (Figure 69). Thus the logged real-time attitude data in the .all file is valid at the transmitter and in the transmitter frame. Because the real time solution is provided as vessel (reference point) relative x, y, and z sounding locations, the navigation data is not translated.

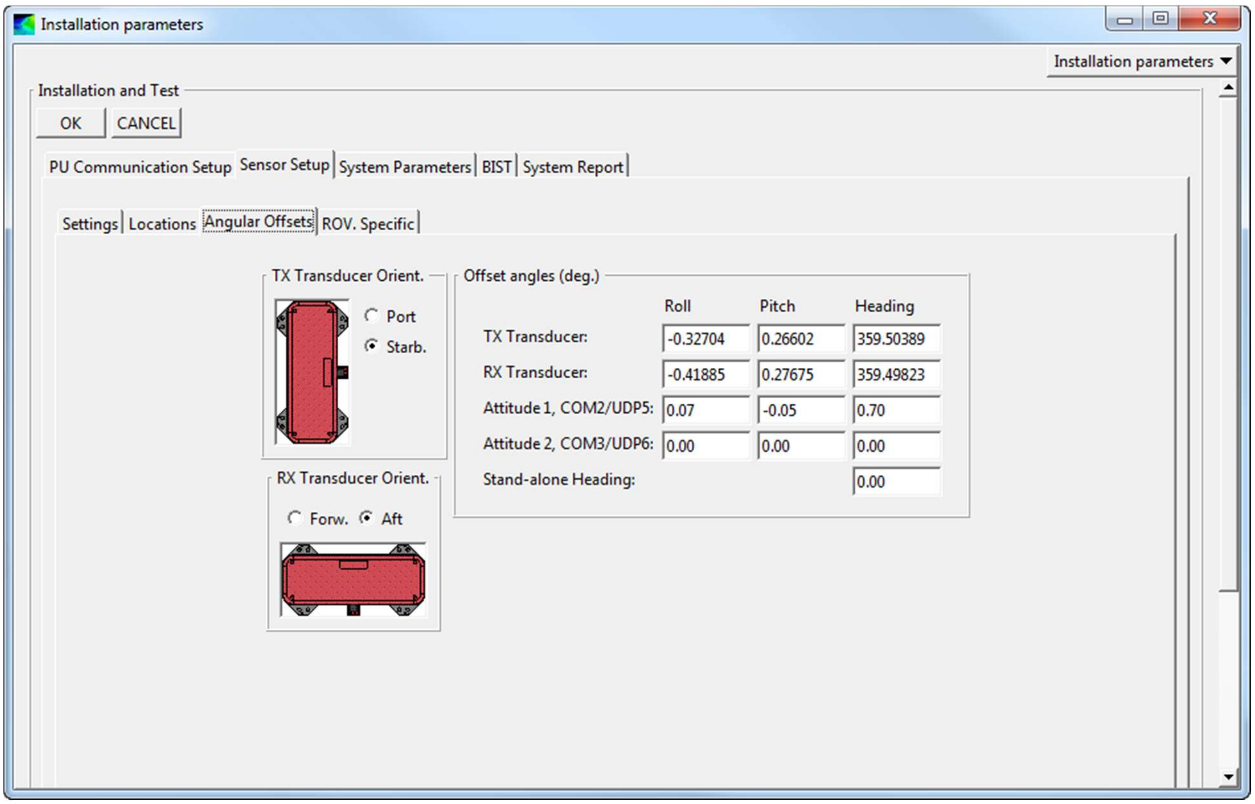



*Figure 68 - The Installation and Test Parameters, Sensor Setup, Angular Offsets for the NOAA Ship Thomas Jefferson EM2040.*

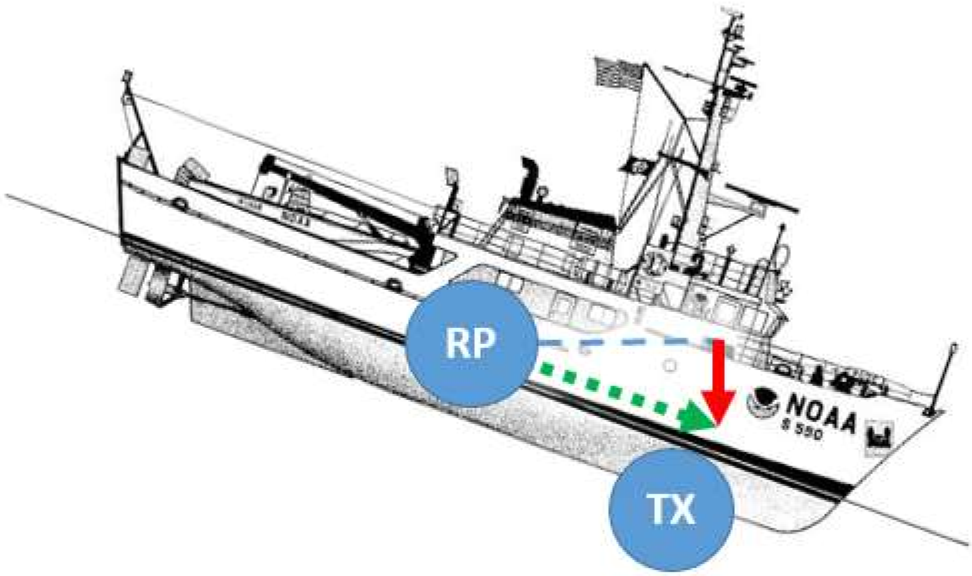



*Figure 69 - Pitched induced heave (red arrow) is a result of the along track lever arm between the reference point (RP) and transducers (TX).*

In summary: the SIS logged real-time attitude (including heave) is valid at the transmitter and in the transmitter frame; real-time navigation, including GNSS height information (e.g. GGK and EM Height records), are valid at the ship reference point.

This difference in reference frames only becomes an issue in Caris HIPS when applying post-processed navigation and attitude data. The primary reason for post applying any post-processed data is the quality of the vertical information. Delayed heave or a post processed ellipsoid height can both significantly improve on the real time solution, so it is desirable to have the option to apply these adjustments in post processing. While a vertical offset can be straightforward to apply, the valid location of the available vertical positioning data is important for proper accounting for the effects of the motion induced heave.

Caris HIPS is designed around the integration of sensor data described in a single reference frame with one sensor for each type of data. The Hydrographic Vessel File (HVF) describes the offsets between the different sensors being integrated and accounts for those offsets where required. Processing Kongsberg multibeam data within this framework is complicated by the existence of two possible reference frame existing within the provided data. While in general Kongsberg data is meant to provide all data in the vessel reference frame (patch test values are applied to motion information, ray traced soundings, etc), real time heave and all raw transducer data (ranges and angles) are also provided in the transducer reference frame. The Caris HVF accounts for this dual state by not applying any motion (everything is apply = no) or offsets (Swath offsets are zero) when the real time ray-traced solution is imported, but does account for these offsets or motion when reprocessing during ray tracing (SVC). This is the reason for the transducer lever arms provided in the SVP portion of the HVF. In theory reintegrating the motion information is straightforward because all lever arms and angular offsets have already been applied to the Kongsberg data. Problems do arise when the data provided in post processing are not in the same reference frame as the Kongsberg frames. In our case, delayed heave or GPS height information. HIPS can handle different configurations, but a different HVF may be required depending on the sensor and workflow (e.g., SVC or no SVC, true heave or real time heave). Most significant to this discussion of the HVF configuration is the description of the heave sensor location- as configured, the real-time heave is reported in a different place than the delayed heave, but there is only one 'heave' field in the HVF.

It would seem the logic of the HVF would require a lever arm for the heave sensor when using Kongsberg real time heave (Kongsberg reported heave has the induced heave included and is therefore valid at the transducer as mentioned previously), but the HVF requires no offset for the heave sensor when reintegrating the real time heave during SVC. All other data is either valid at the reference point or has offsets as described by the Caris technote on converting Kongsberg data [8]. This inherently calls into question the reference frame of the HVF for Kongberg data – is the HVF in the vessel reference frame or the transducer reference frame? When conducting SVC in HIPS the reference frame appears to be in the transducer reference frame (with the exception of the SVP fields). When no SVC is conducted the reference frame appears to be in the vessel reference frame.

When no SVC is conducted, the description of the heave sensor lever arm is only important for computing GPS Tides. For the proper removal of heave from the GPS tide height, the HVF heave sensor field must have a lever arm equivalent to the distance from the reference point to the transmit transducer. When computing GPS Tides the "MRU remote heave" box must be checked such that the heave is moved back to the reference point and properly applied to the GPS height. While this is essentially the desired workflow, i.e. all data is to the ellipsoid using all real time data, this method was deemed too inflexible since it precluded a water level referenced workflow free from heave artifacts. Because the position of the heave sensor is ambiguous (real time heave is at the transducers but delayed heave is at the reference point), there is not a way to apply delayed heave during merge only in HIPS. While the difference between real time and delayed heave is the same everywhere on the vessel, this difference needs to be computed at the same location such that the induced heave is canceled out. It is possible to compute this difference directly from the Applanix True Heave record where both the real and delayed heave are reported, but HIPS differences the delayed heave with the real time heave from the Kongsberg file which adds back the induced heave artifact.

When SVC is conducted in HIPS the HVF appears to describe the sensors in the transducer reference frame. SVC may be conducted with zero offsets for all sensors besides the transducers, and results comparable to the real time reported values are produced. The computation of GPS Tides is complicated by the fact that the valid location of GPS tides is at the reference point and not at the transducer, and there is no entry in the HVF for the location of GPS Tides. To circumvent this problem delayed heave must be applied to the data. By including an entry in the HVF that describes the location of the reference point, and thereby delayed heave, for the heave sensor relative to the transmit transducer, heave is correctly applied to the bathymetry. This means a lever arm *opposite* to the SVP1 field is entered for the heave sensor and provides for an SVC inclusive workflow that references the survey to the waterline. To compute GPS tides the "MRU remote heave" box is *not* check because delayed heave and the GNSS height are both already at the reference point. While this workflow requires delayed heave and the SVC step in post processing, it provides for the most flexible workflow and is recommended for *Thomas Jefferson* with their current configuration.

The application of "Waterline" during the computation of GPS tides also deserves discussion here. If data are converted with the GPS Height as GGK then the waterline needs to be applied during GPS Tide.

Because SIS applies the waterline value from the Installation Parameters to the EM Height, if the data are converted with GPS Height as EM Height the water line does not need to be applied when computing GPS tides. For this reason the recommended workflow for *Thomas Jefferson* is to convert with EM Height but not apply waterline during the GPS Tide computation.

While much of this confusion could be alleviated if Caris accommodated multiple potential heave sensor (e.g. real-time, post-processed) within the HVF (i.e. the real time Kongsberg reported heave required a lever arm entry), Caris stated in the helpdesk ticket while exploring this problem that their HVF configuration will not be revisited until Caris HIPS 11. For a discussion of this solution please see the NOAA - Caris helpdesk ticket request ID 01602680.

To accommodate the current processing restrictions, maximize potential workflow flexibility, and limit the number of unique HVF files, we implemented the following workflows:

1) ERS
    a. Convert MBES data → Load Delayed Heave → Sound Velocity Correct → Compute GPS Tides → Merge with GPS Tides → TPU

2) Traditional Water Levels
    a. Convert MBES data → Load Delayed Heave → Load Tides → Sound Velocity Correct → Merge → TPU

*Thomas Jefferson's* HVF has also been modified to account for Total Propagated Uncertainty (TPU) with MarineStar (which does not have real time uncertainty reported correctly), but again to maximize flexibility while limiting unique HVFs. Entries associated with the real time water level reference uncertainty, such as heave, static and dynamic draft, which together have a root sum square value of 0.09 m, have been removed from the HVF. When surveying to the ellipsoid, a value of 0.11 m for the MarineStar uncertainty is entered into the Tide/Measured dialog. This value was derived as an average of all 2015 *Thomas Jefferson* ship (no launches) POSPac PPP projects compiled by Physical Scientist Faulkes. The VDatum uncertainty from the project instructions is entered into the Tide/Zoning dialog. When surveying to the waterline, the Tide/Measured dialog will include the values that were removed from the HVF as a single value of 0.09 m, and the projects instructions will inform the value for the Tide/Zoning dialog.

For details, please see the Standard Operating Procedure for *Thomas Jefferson's* Caris HIPS configuration and conversion in the appendix.

## 7.2 Test data resolution and density

As with past Kongsberg multibeam echo sounders, *Thomas Jefferson's* survey system meets Coast Survey sounding density specifications. The density estimates, as calculated from the extinction lines, for the EM2040 can be found in Figure 70, and the EM710 in Figure 72. Ping rates as measured from these same data can be found in Figure 71 and Figure 73 for the EM2040 and EM710 respectively. Unfortunately, the EM2040 extinction was not tested specifically in shallow water where the density estimate would be most applicable. Past testing with the EM2040 [10] demonstrates that the EM2040 will meet NOAA density specifications in shallow water.

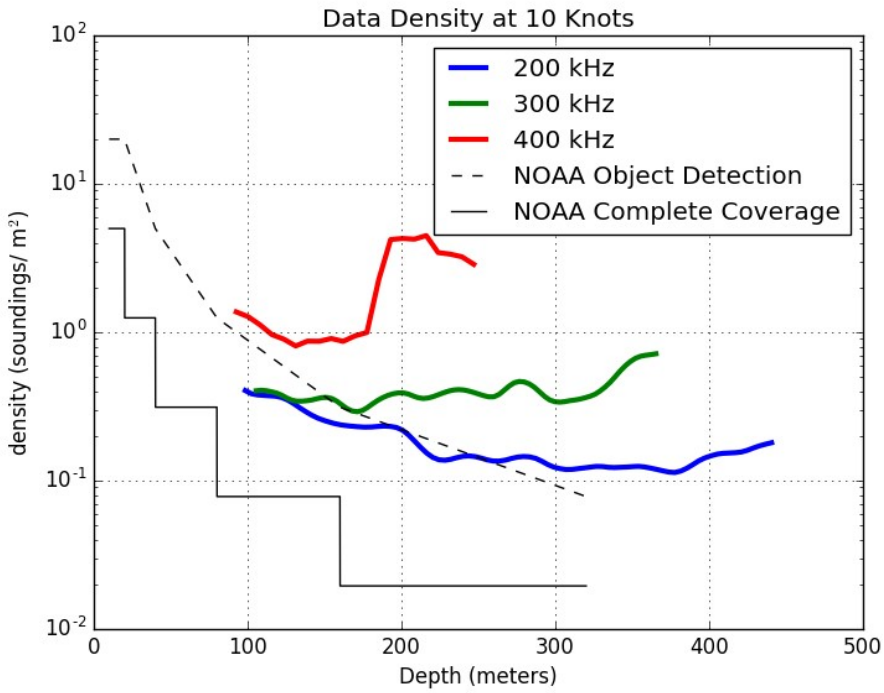



*Figure 70 – Sounding density for the EM2040 estimated from the extinction lines.*

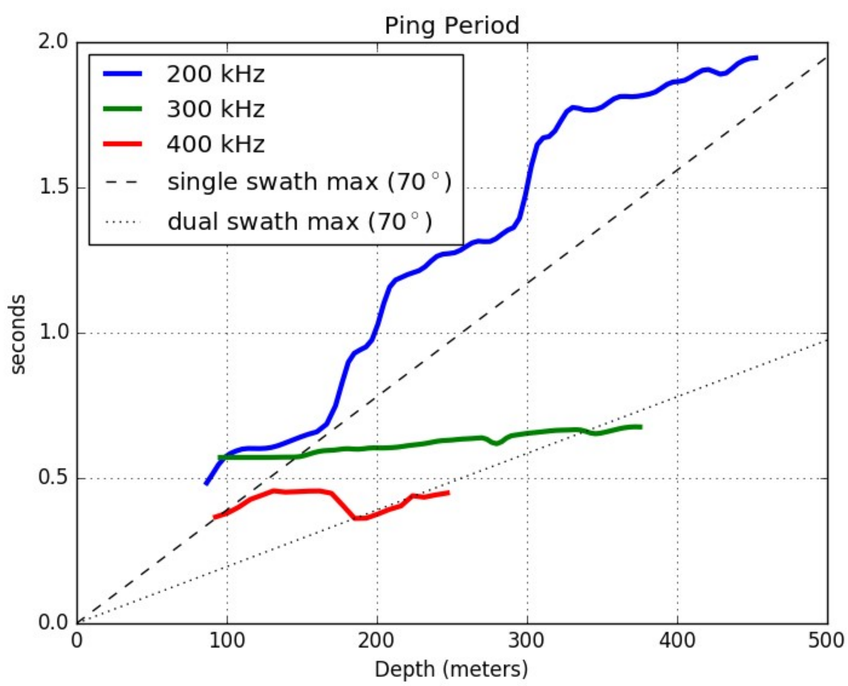



*Figure 71 – Ping periods for the EM2040 during the extinction lines.*

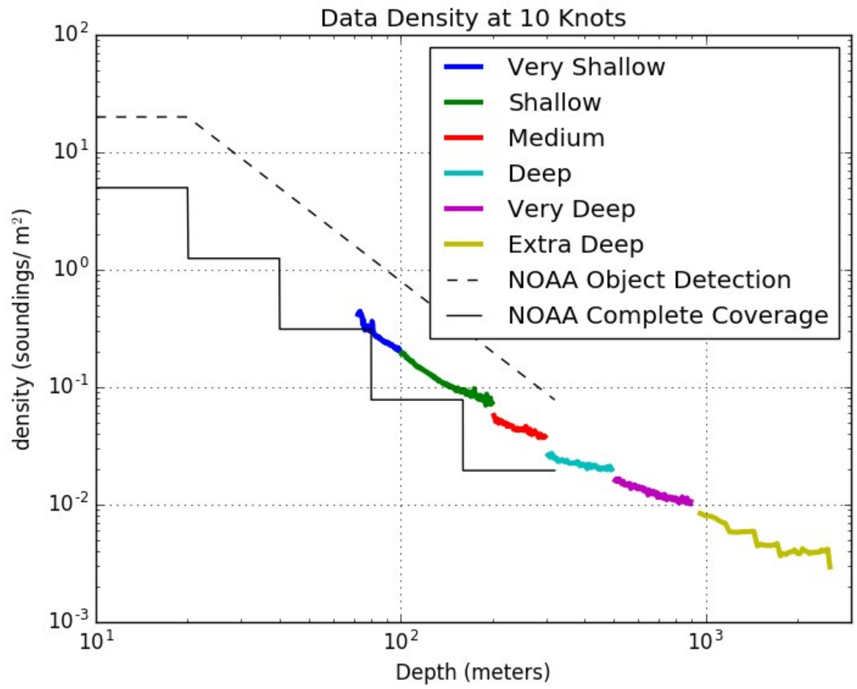



*Figure 72 – Sounding density for the EM710 estimated from the extinction lines.*

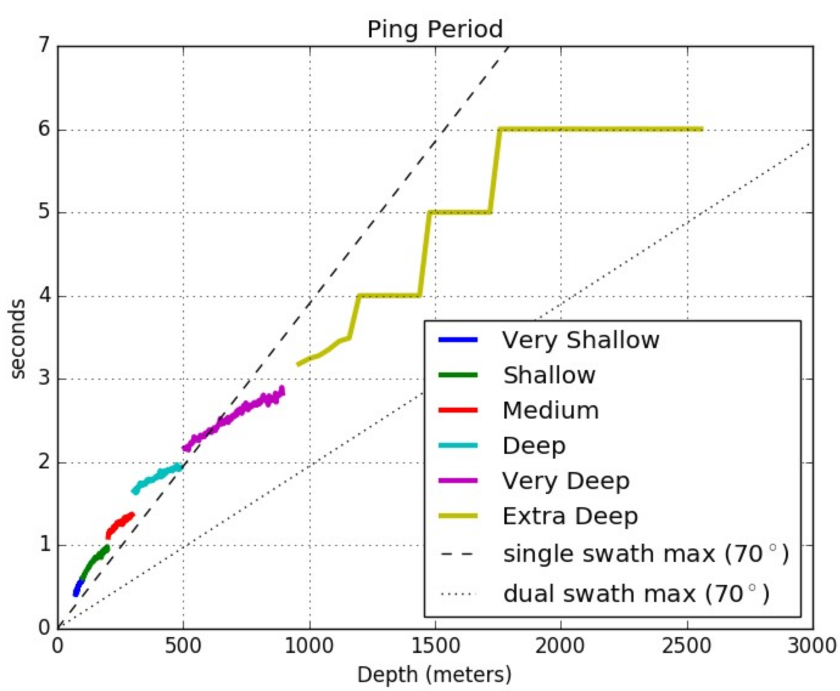



*Figure 73 – Ping period for the EM710 during the extinction lines.*

## 7.3 Test total propagated uncertainty

Kongsberg produces real time uncertainty for the echo sounder component of the uncertainty model according to the method recommended by Ifremer [9]. These records can be ingested by Caris to contribute toward the sonar portion of the Total Propagated Uncertainty (TPU). Data were evaluated using data collected during the object detection portion of this cruise and using the HIPS configuration described in 7.1. For reference, IHO Order 1a for 75 meters of depth is 1.1 meters. At nadir the uncertainty was 0.406 meters, and for the outer beams it was 0.737 meters.

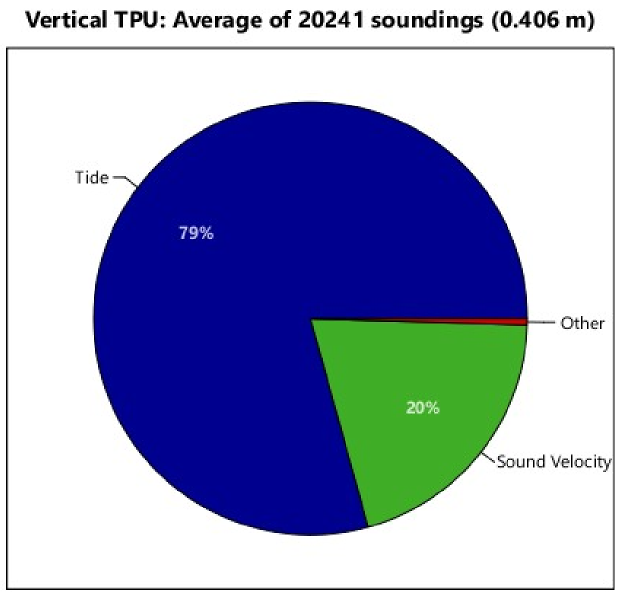



*Figure 74 - Nadir Total Vertical Uncertainty breakdown by contribution source for the EM2040. The real time uncertainty from the echo sounder is small and included in the "Other" portion of the plot.*

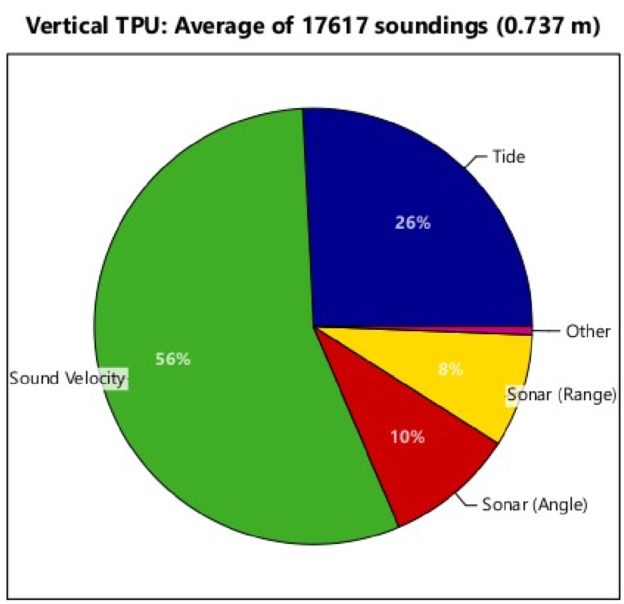



*Figure 75 – Outer beam Total Vertical Uncertainty breakdown by contribution source for the EM2040. The contribution from the echo sounder real time uncertainty is small relative to other factors.*

Both Figure 74 and Figure 75 demonstrates that the EM2040 real time echo sounder uncertainty is not a major contributor to the total uncertainty and that the Caris HIPS configuration can be expected to meet IHO Order 1a specifications for uncertainty.

### 7.4 Difference Surface

The object detection lines from the vicinity of the wreck of the Bow Mariner were used to compare the fully integrated EM710 and EM2040 survey depths against previous data collected by NOAA Ship *Thomas Jefferson* during survey F00585. All *Thomas Jefferson* acceptance survey data was collected to the ellipsoid, so an offset between ITRF 2008 and mean lower low water of -38.6 meters at the Bow Mariner location was computed using VDatum. This offset was used to shift data to the same datum as the previous *Thomas Jefferson* survey. The difference surface statistics between the previous Reson 7125 and the new EM710 and EM2040 are described in Table 6. Also included in this table are difference surface statistics between *Thomas Jefferson's* EM2040 and survey H11504 by David Evans and Associates, which happened to cover some preliminary data collected with the new EM2040 before the acceptance cruise. Patch test values were applied in post processing for these data, and the sound speed cast was adjusted to account for the faulty sensor present during preliminary testing (see 4.2.3).

*Table 6 - Difference surface statistics as computed within Caris HIPS.*

| Location and System | Mean Offset (m) | Standard Deviation (m) |
|---|---|---|
| Bow Mariner – EM710 | -0.3 | 0.2 |
| Bow Mariner – EM2040 | -0.2 | 0.1 |
| Chesapeake Bay – EM2040 | 0.2 | 0.1 |

While there appears to be a consistent bias at the Bow Mariner site compared to the previous Reson 7125 survey data, there is good agreement between the *Thomas Jefferson* EM710 and the EM2040. When considering this agreement with the opposing offset in the difference between previous survey coverage and Thomas Jefferson's EM2040 at the two different locations, the bias may not be due to an offset internal to the survey system but in realizing the vertical datum. The uncertainty in realizing the vertical datum (VDatum and the MarineStar Service) is approximately 0.14 meters at two standard deviations. Since the mean uncertainty for the F00585 and H11504 surveys were 0.55 meters and 0.41 meters respectively (both vertically referenced through tide zoning), *Thomas Jefferson* appears to be configured to produce properly vertically referenced soundings with the new survey system.

## 8 Concluding Summary

Two new Kongsberg multibeam echo sounders have been added to the NOAA Hydrographic fleet aboard NOAA Ship *Thomas Jefferson*. While the EM710 and EM2040 appear to be functioning as specified and are integrated with the supporting sensors correctly, two residual problems remain.

The primary problem is a leeward bathymetric artifact effecting both the EM2040 and EM710. While an initial step to remedy this problem has been taken by removing the line guard in front of the transducer mount, further testing is required to evaluate if the problem is resolved. If the problem is not resolved further steps will need to be taken to better characterize the source of the problem and engineer a fix.

The second problem is an artifact with the EM2040 200 kHz mode. Kongsberg recommendations to resolve this problem have already been implemented and testing is required to understand if the issue persists.

*Thomas Jefferson* has a workflow that will provide both ellipsoid and water level derived results in Caris HIPS. While this workflow unfortunately does not take advantage of the real time GPS height and ray traced bathymetry, it does meet the requirements of the ship despite being more cumbersome.

The EM2040 Min Depth detection mode was compared to the Normal detection mode and found to improve the recognition of features that reflect man made construction. While this mode is useful for developments, it should not be used for general bathymetry to avoid collecting data on fish schools.


### *Acknowledgements*

We would like to recognize the ship and CDR Moser for their struggle and effort to get underway and operate the ship in new ways after being land bound for six months. The flexibility and hard work of the acceptance crew is also recognized. Jack Riley was particularly instrumental in producing some of the plots for this report and also, in addition to LCDR Sam Greenaway and John Doroba, for helping get the Caris HIPS workflow sorted out. The help of Eric Younkin and Matt Wilson in alongside preparation was also appreciated.


# 9 References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[8] Caris Customer Services. (2014, Oct). Sound Velocity Corrections for Kongsberg EM Data. [Online] Available with login: http://support.caris.com/technical_notes/hips/TechNote%20-%20HIPS%20-%20SV%20Corrections%20for%20Kongsberg%20EM%20Data.pdf

[9] X. Lurton and J.M. Augustin, "A Measurement Quality Factor for Swath Bathymetry Sounders,", IEEE J. of Ocean. Eng., Vol 35, No. 4, Oct, 2010.

[10] G. Rice, "Bay Hydrographer II EM2040 Testing of Acceptance Testing," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep, 2016.

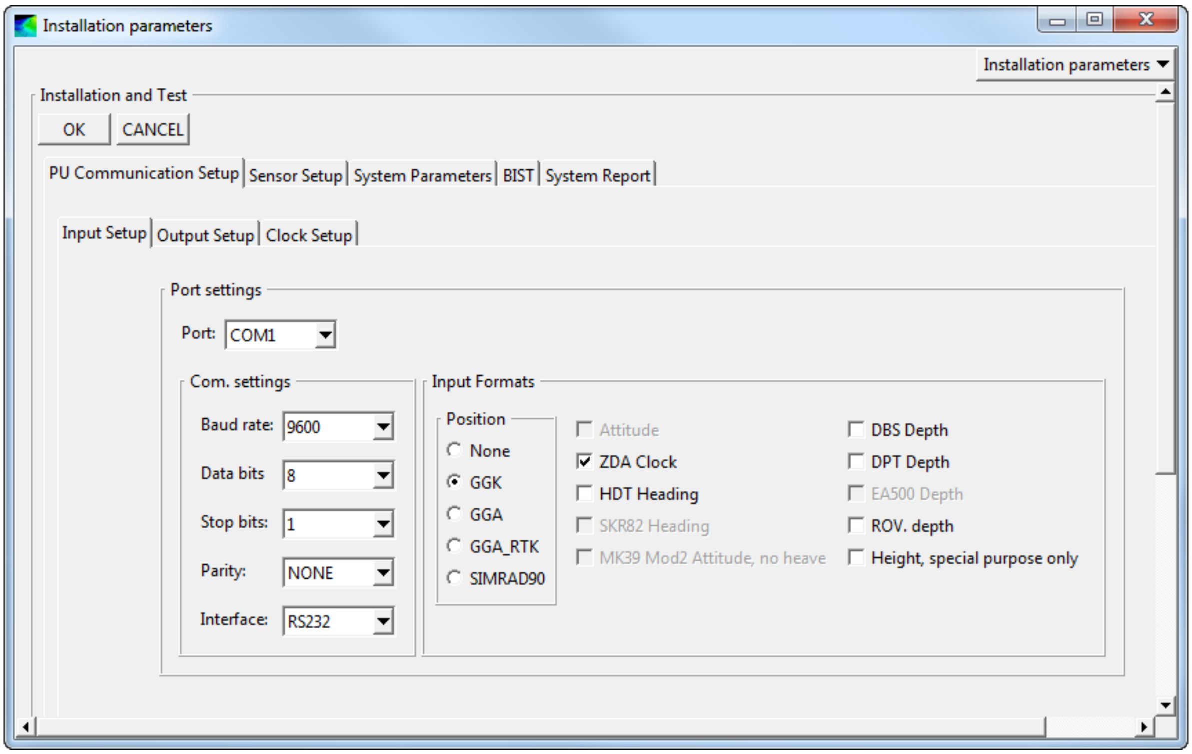
# 10 Appendices

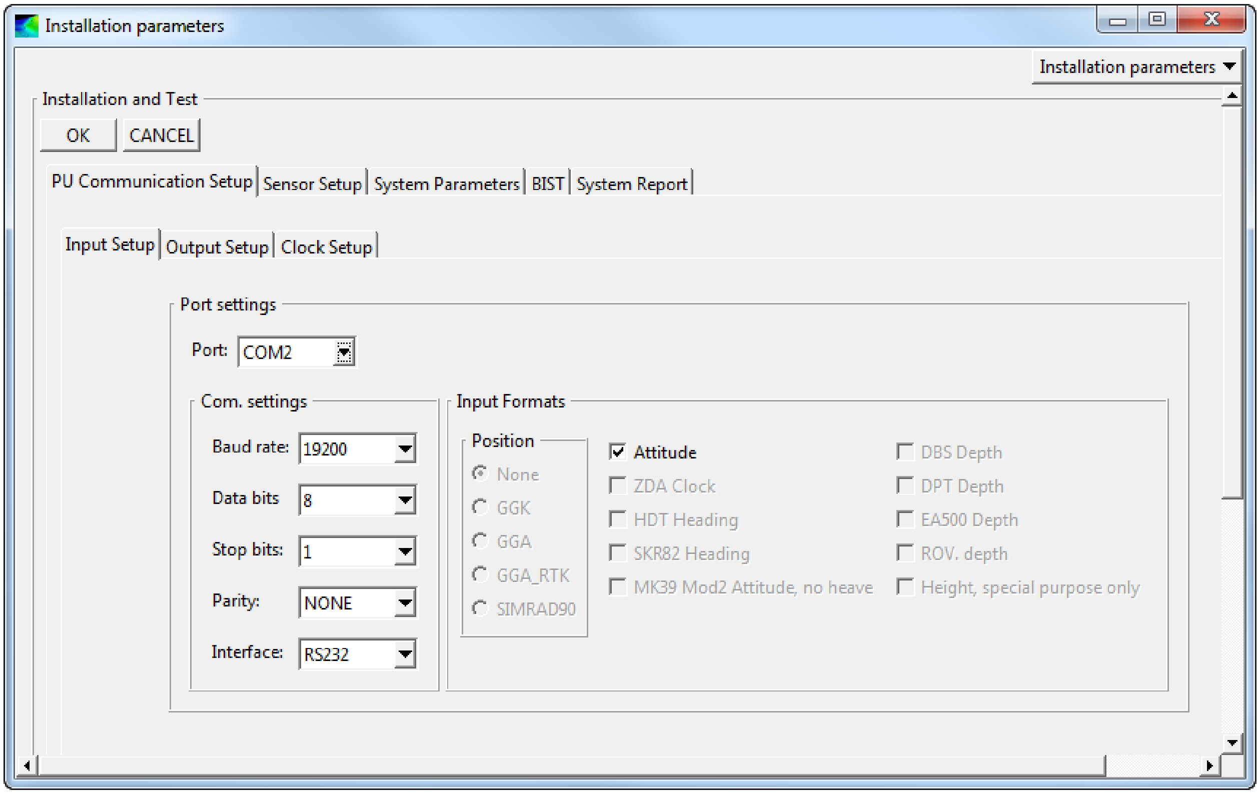


## 10.1 Configuration Screen Grabs

### 10.1.1 SIS

#### *10.1.1.1 EM2040*

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GGA_RTK
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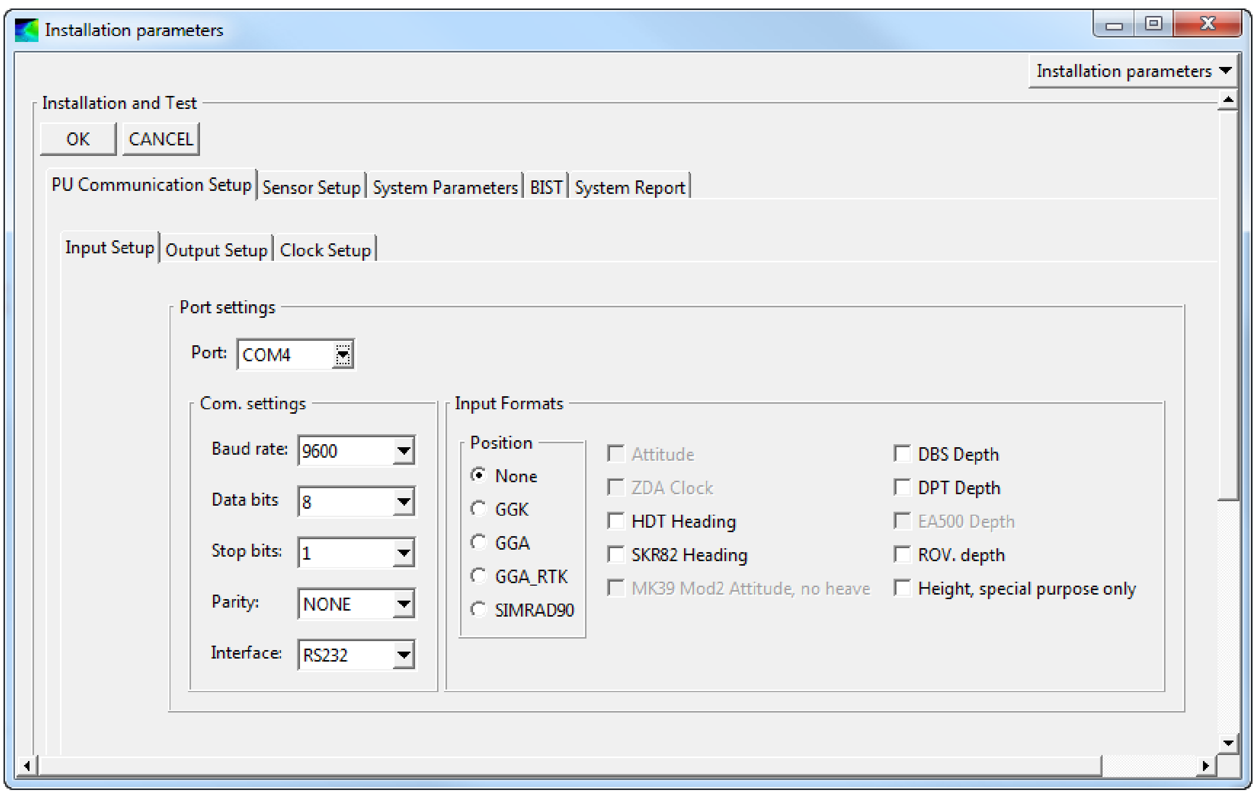
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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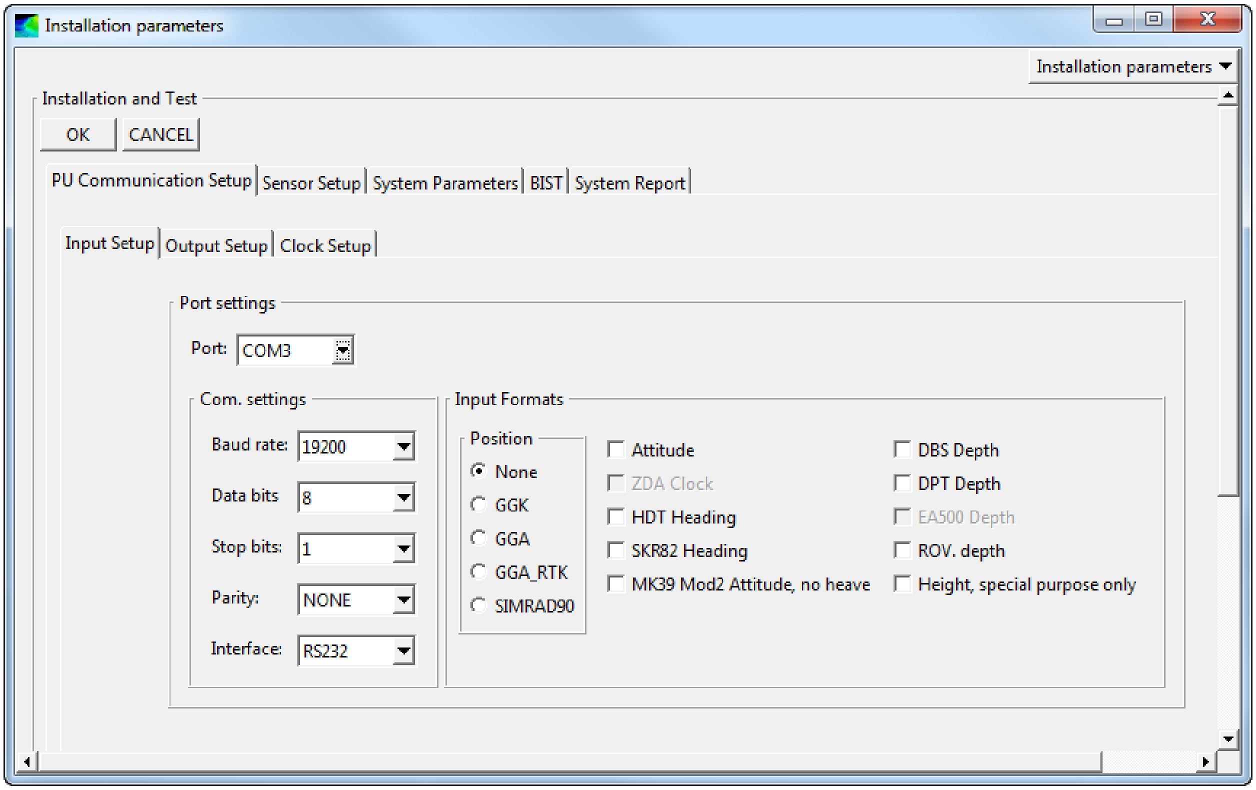
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only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GGA
GGA_RTK
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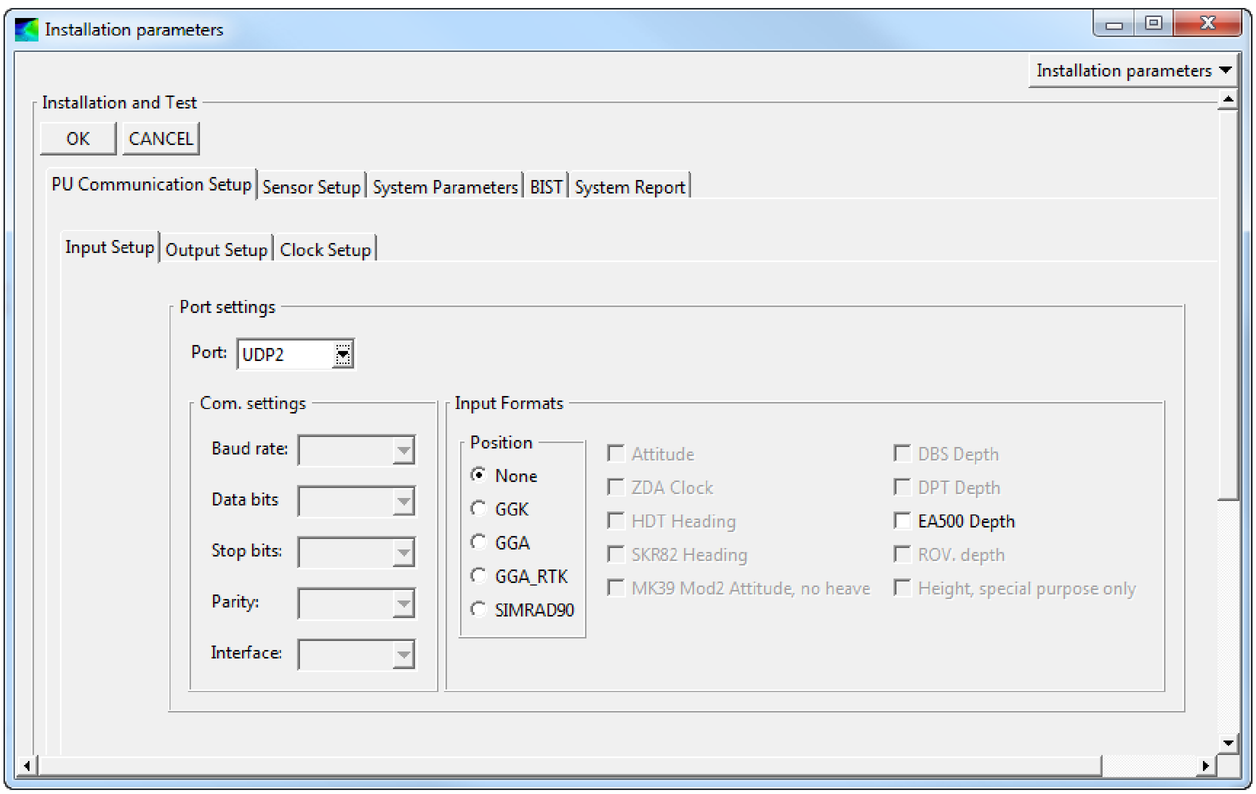
ROV. depth
Height, special purpose only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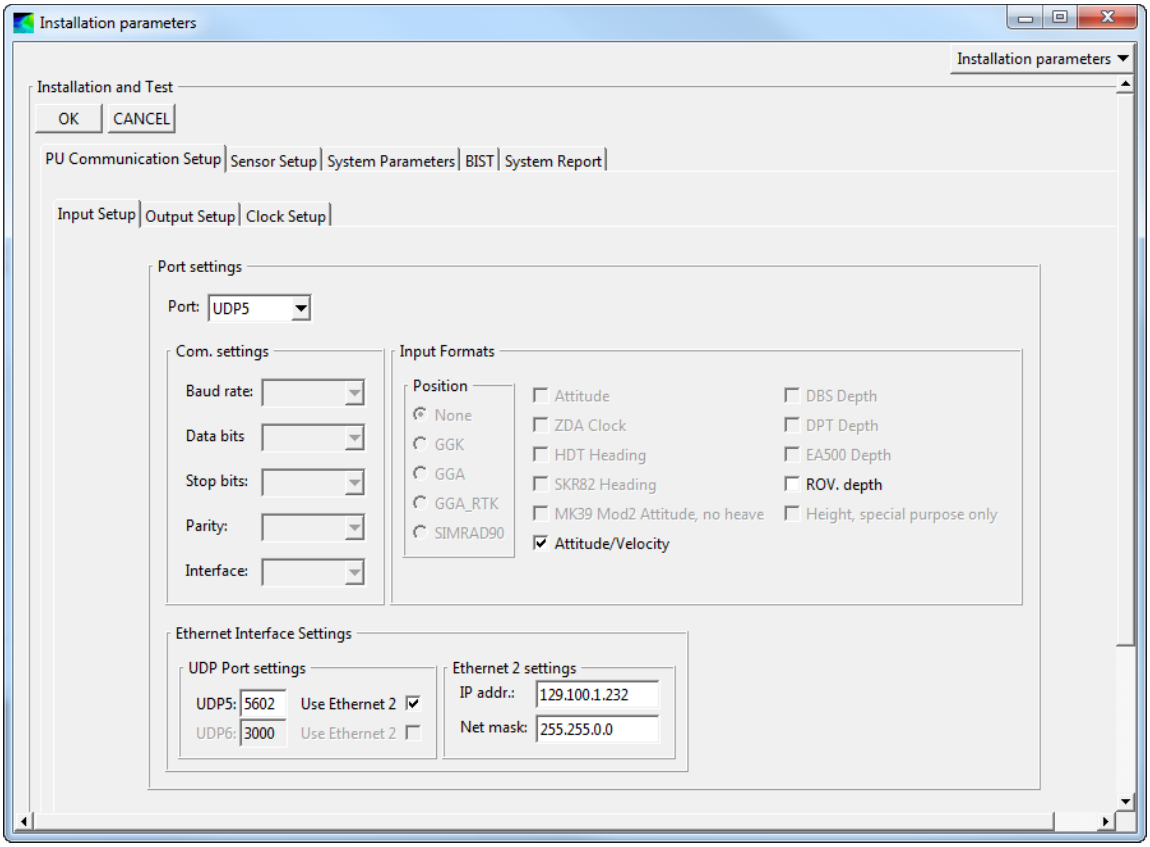
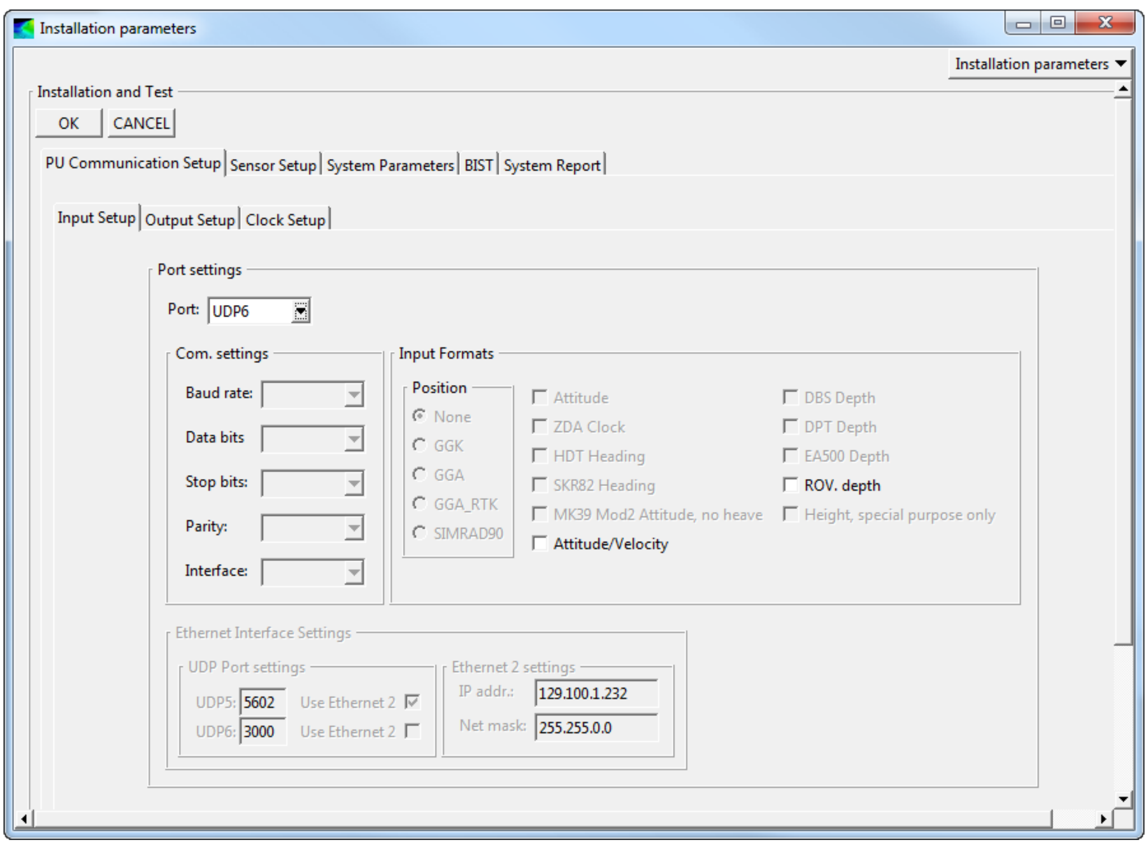
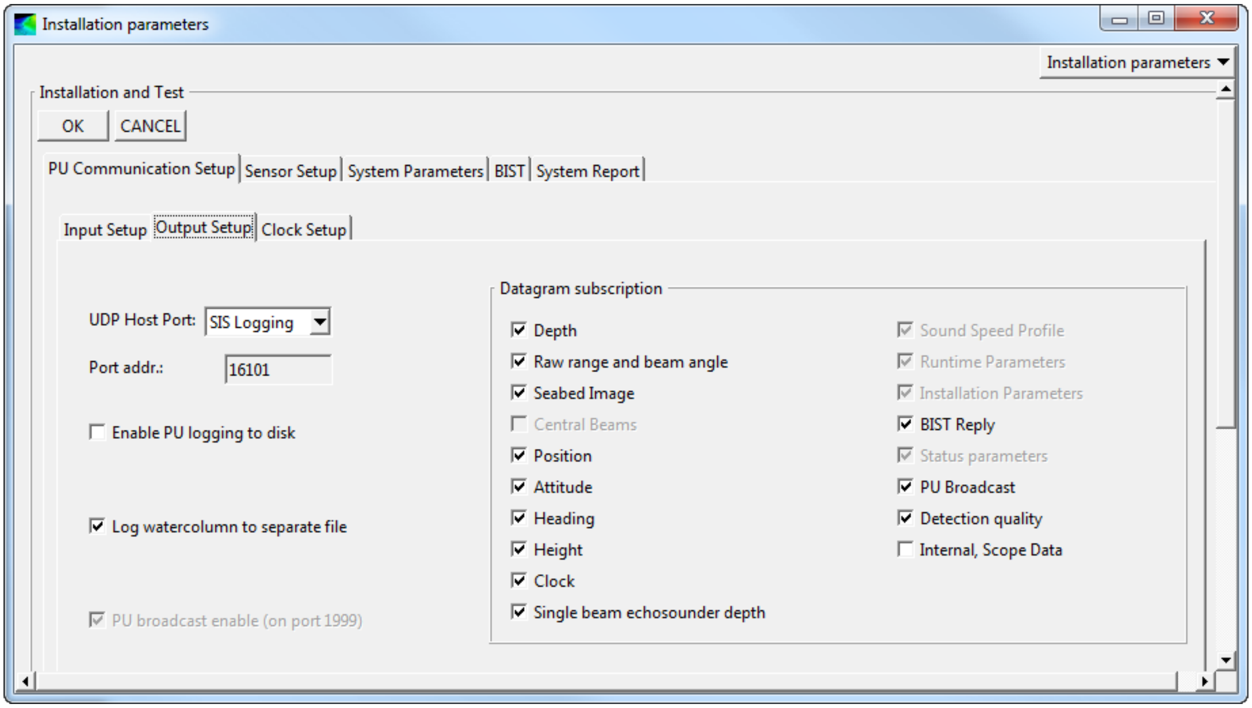
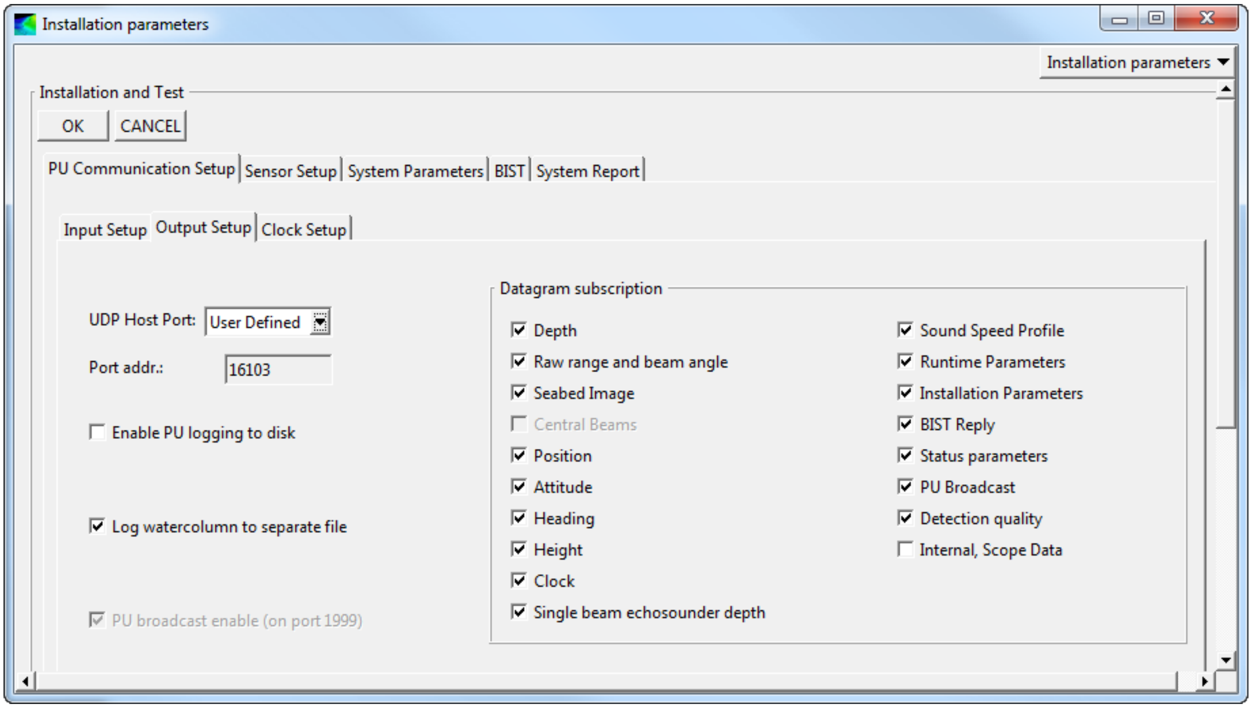
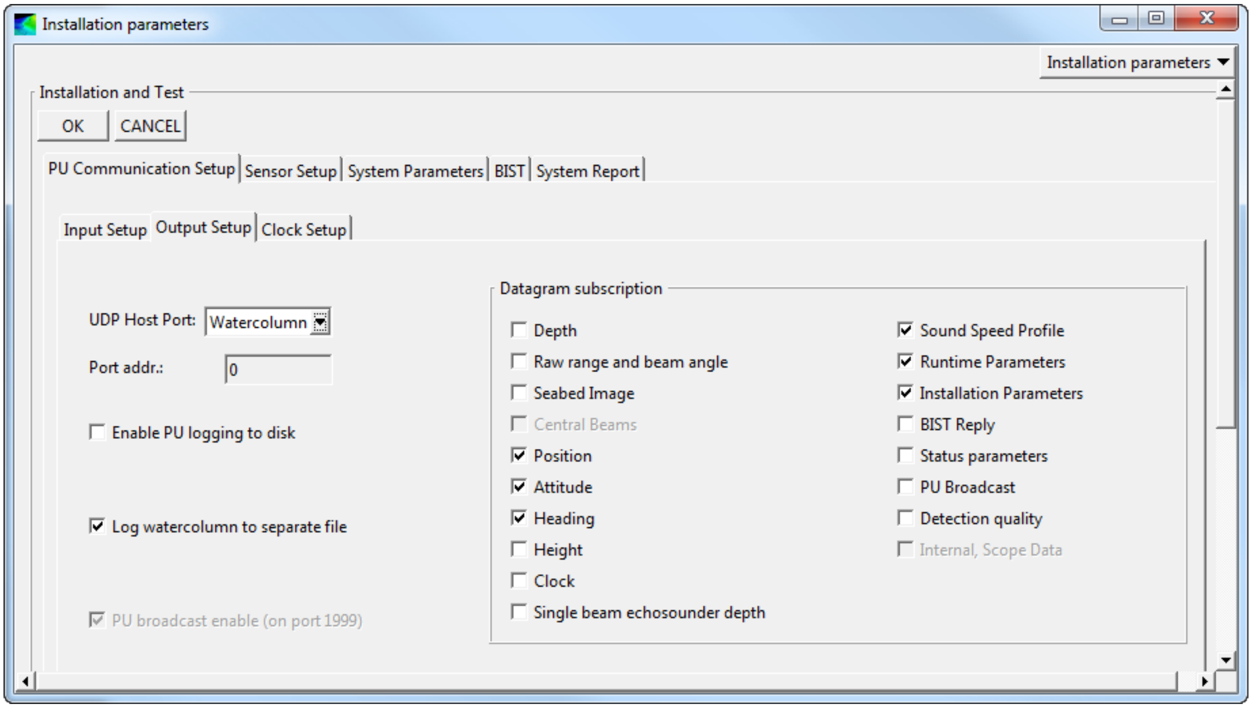
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only

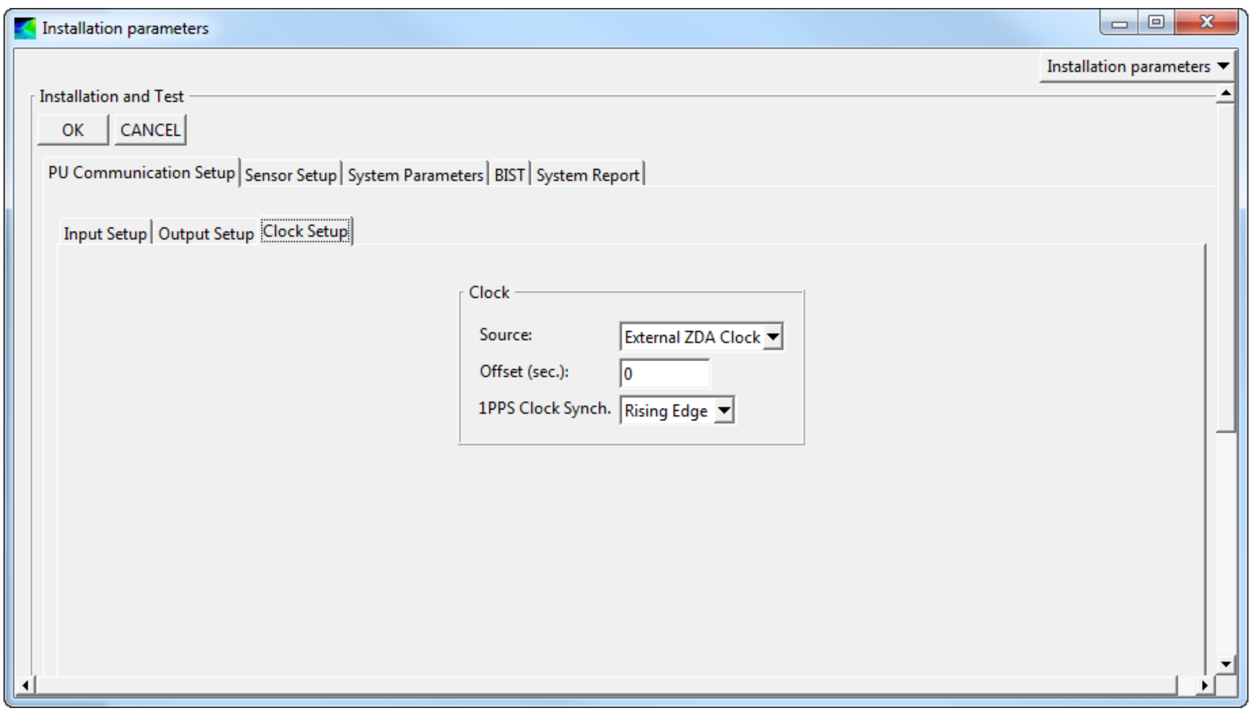

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP5
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Attitude/Velocity
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
Ethernet Interface Settings
UDP Port settings
UDP5: 5602 Use Ethernet 2
UDP6: 3000 Use Ethernet 2
Ethernet 2 settings
IP addr.: 129.100.1.232
Net mask: 255.255.0.0

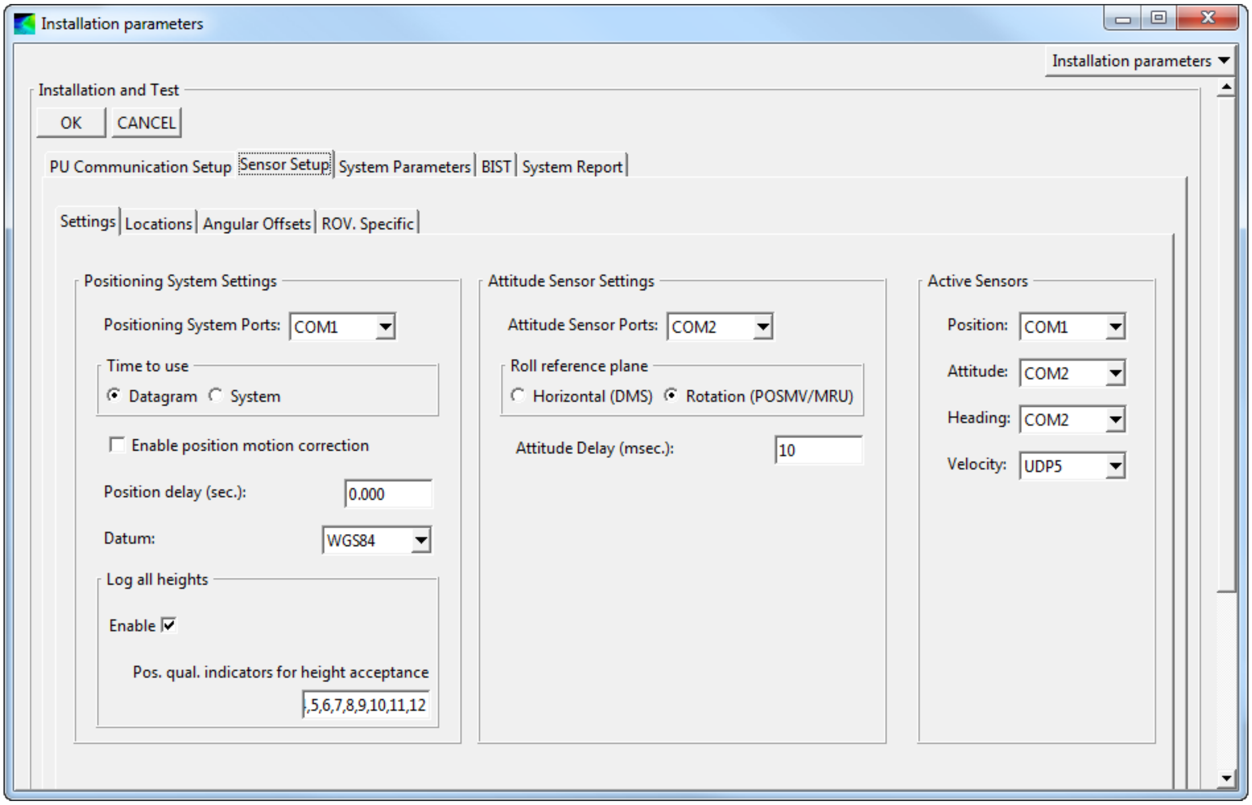

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP6
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Attitude/Velocity
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
Ethernet Interface Settings
UDP Port settings
UDP5: 5602 Use Ethernet 2
UDP6: 3000 Use Ethernet 2
Ethernet 2 settings
IP addr.: 129.100.1.232
Net mask: 255.255.0.0

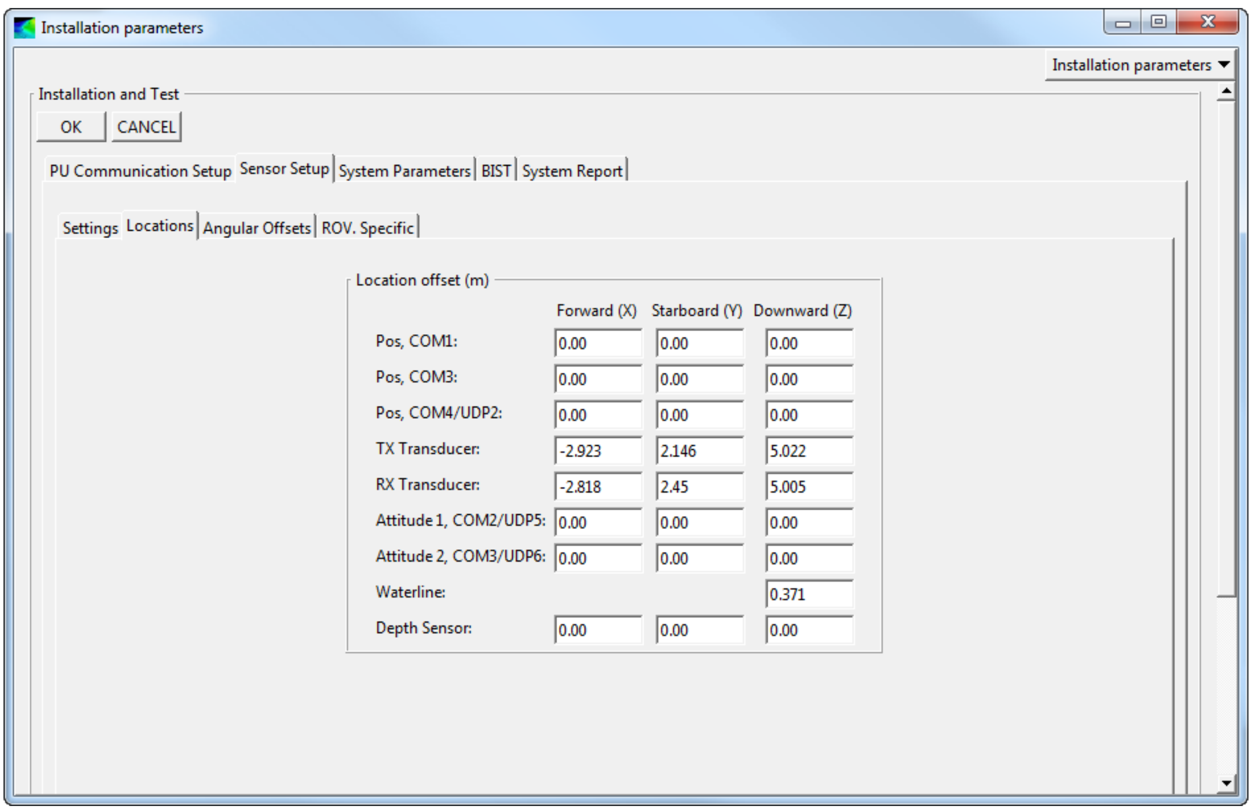

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
SIS Logging
Port addr.:
16101
Enable PU logging to disk
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

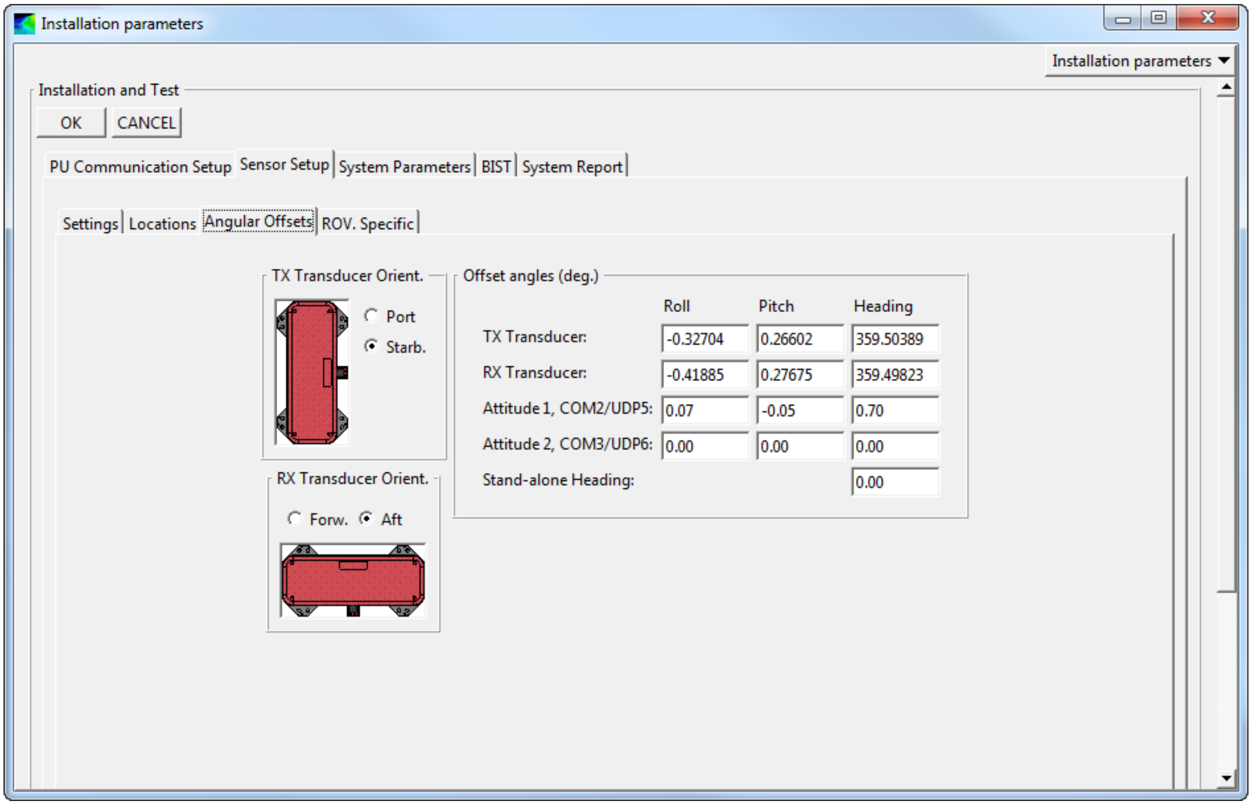

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
User Defined
Port addr.:
16103
Enable PU logging to disk
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

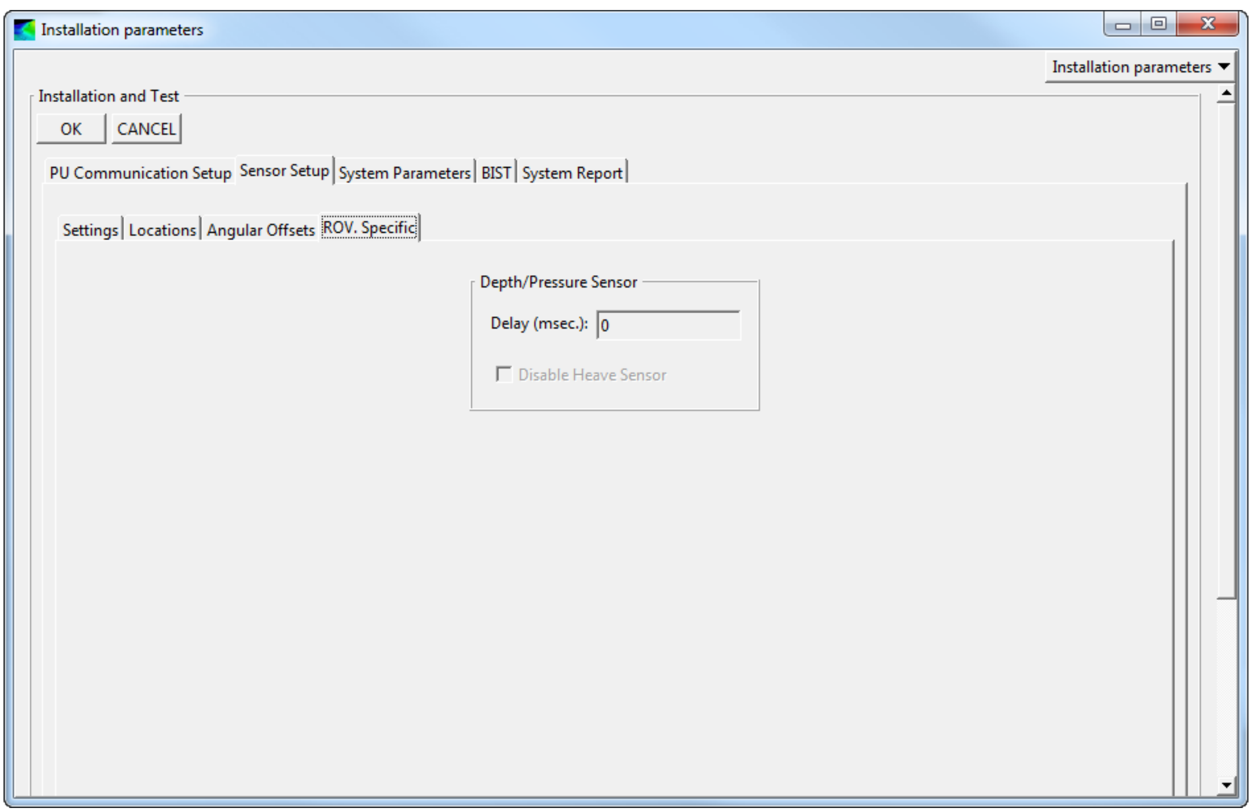

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
Watercolumn
Port addr.:
0
Enable PU logging to disk
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

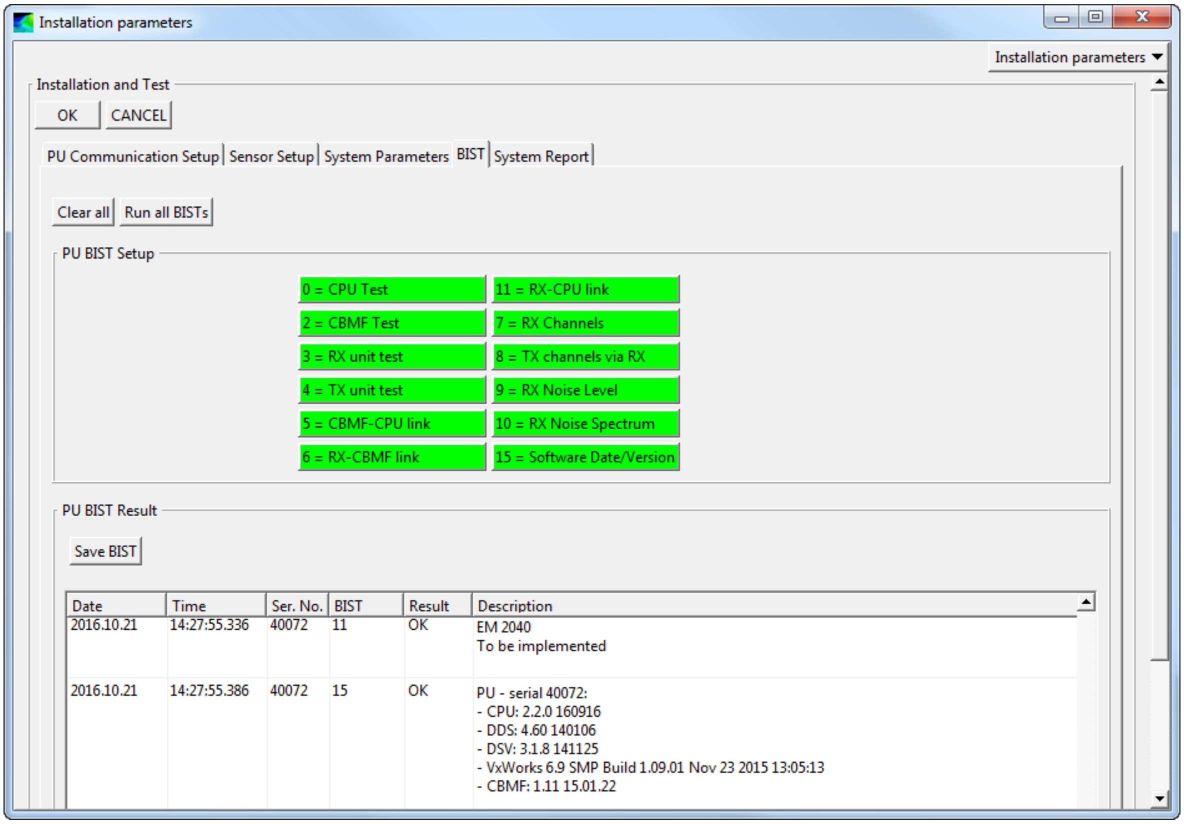

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Clock
Source:
External ZDA Clock
Offset (sec.):
0
1PPS Clock Synch.
Rising Edge

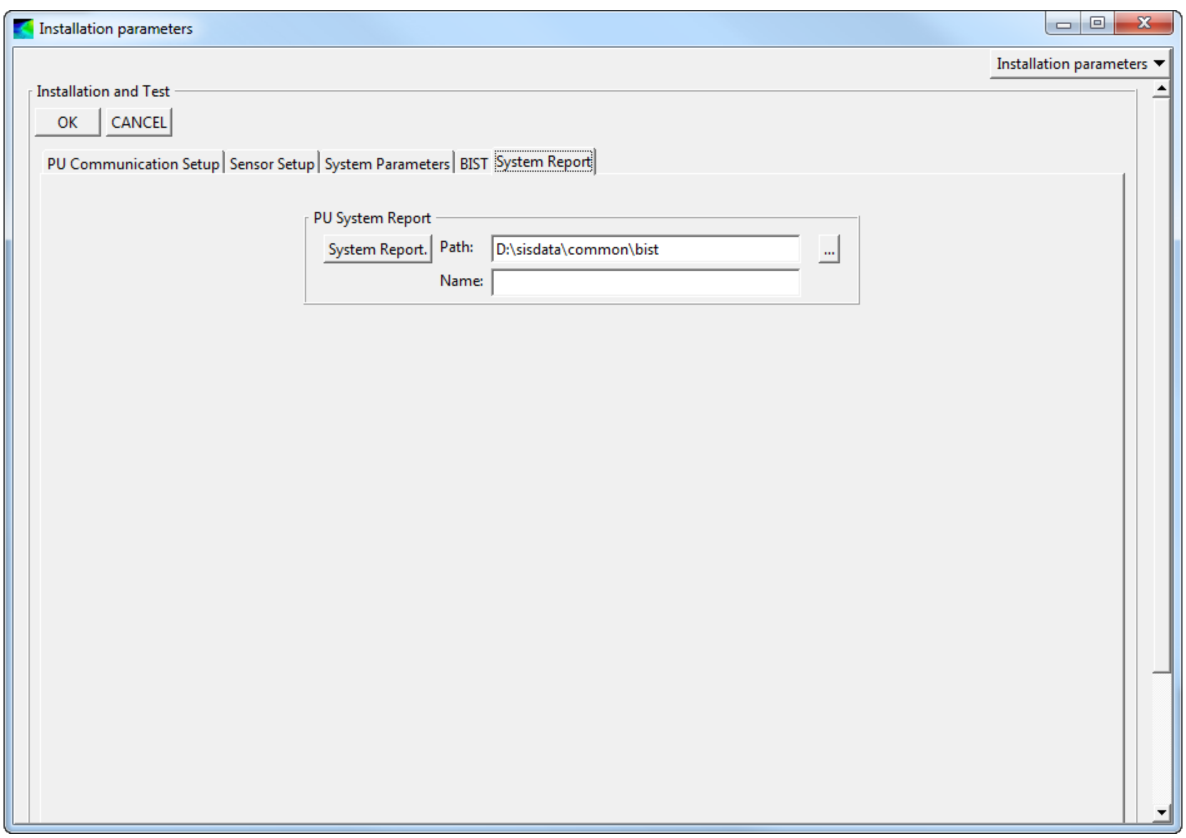

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Positioning System Settings
Positioning System Ports:
COM1
Time to use
Datagram
System
Enable position motion correction
Position delay (sec.):
0.000
Datum:
WGS84
Log all heights
Enable
Pos. qual. indicators for height acceptance
,5,6,7,8,9,10,11,12
Attitude Sensor Settings
Attitude Sensor Ports:
COM2
Roll reference plane
Horizontal (DMS)
Rotation (POSMV/MRU)
Attitude Delay (msec.):
10
Active Sensors
Position:
COM1
Attitude:
COM2
Heading:
COM2
Velocity:
UDP5

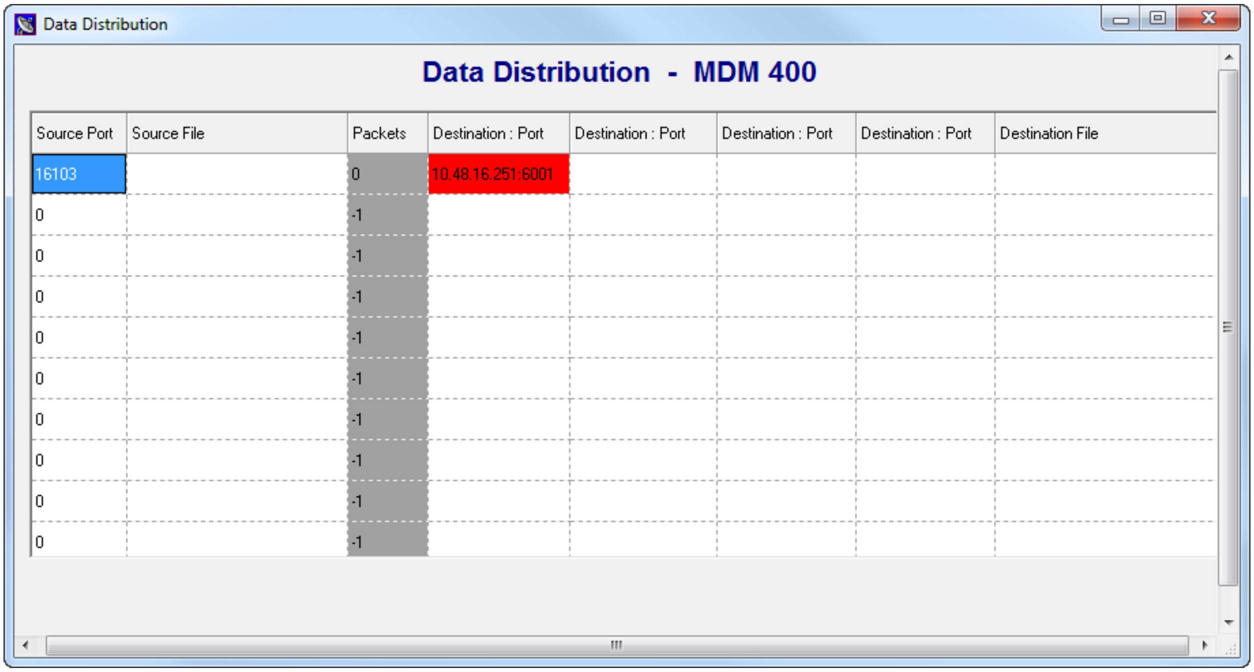

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Location offset (m)
Forward (X)
Starboard (Y)
Downward (Z)
Pos, COM1:
0.00
0.00
0.00
Pos, COM3:
0.00
0.00
0.00
Pos, COM4/UDP2:
0.00
0.00
0.00
TX Transducer:
-2.923
2.146
5.022
RX Transducer:
-2.818
2.45
5.005
Attitude 1, COM2/UDP5:
0.00
0.00
0.00
Attitude 2, COM3/UDP6:
0.00
0.00
0.00
Waterline:
0.371
Depth Sensor:
0.00
0.00
0.00

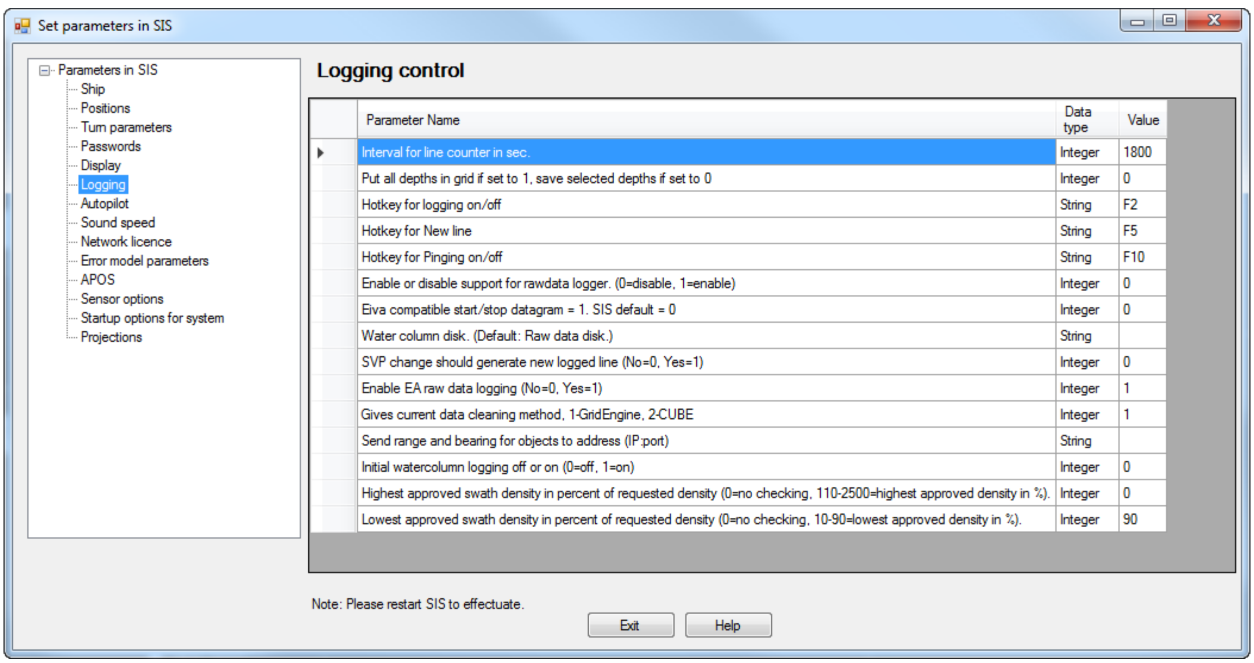

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
TX Transducer Orient.
Port
Starb.
RX Transducer Orient.
Forw.
Aft
Offset angles (deg.)
Roll
Pitch
Heading
TX Transducer:
-0.32704
0.26602
359.50389
RX Transducer:
-0.41885
0.27675
359.49823
Attitude 1, COM2/UDP5:
0.07
-0.05
0.70
Attitude 2, COM3/UDP6:
0.00
0.00
0.00
Stand-alone Heading:
0.00

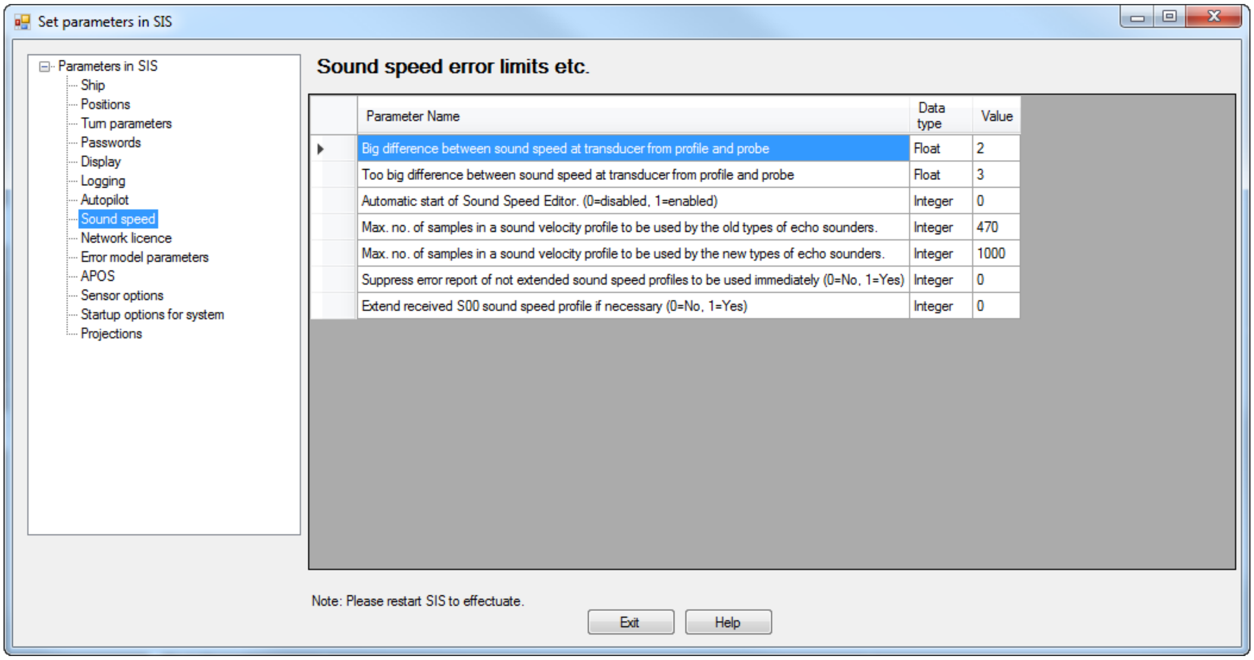

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Depth/Pressure Sensor
Delay (msec.):
0
Disable Heave Sensor

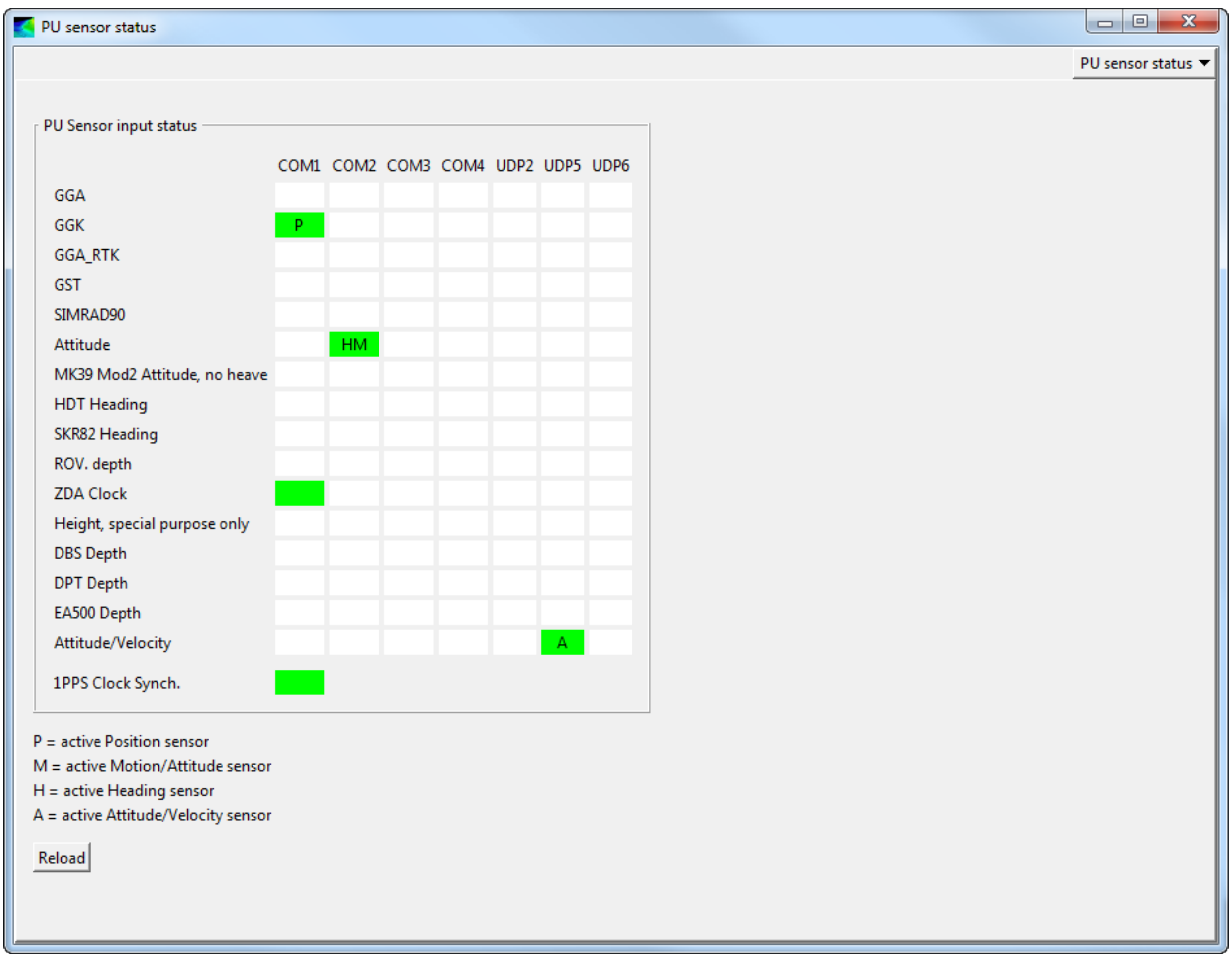

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Clear all
Run all BISTs
PU BIST Setup
0 = CPU Test
11 = RX-CPU link
2 = CBMF Test
7 = RX Channels
3 = RX unit test
8 = TX channels via RX
4 = TX unit test
9 = RX Noise Level
5 = CBMF-CPU link
10 = RX Noise Spectrum
6 = RX-CBMF link
15 = Software Date/Version
PU BIST Result
Save BIST
Date | Time | Ser. No. | BIST | Result | Description
2016.10.21 | 14:27:55.336 | 40072 | 11 | OK | EM 2040
To be implemented
2016.10.21 | 14:27:55.386 | 40072 | 15 | OK | PU - serial 40072:
- CPU: 2.2.0 160916
- DDS: 4.60 140106
- DSV: 3.1.8 141125
- VxWorks 6.9 SMP Build 1.09.01 Nov 23 2015 13:05:13
- CBMF: 1.11 15.01.22

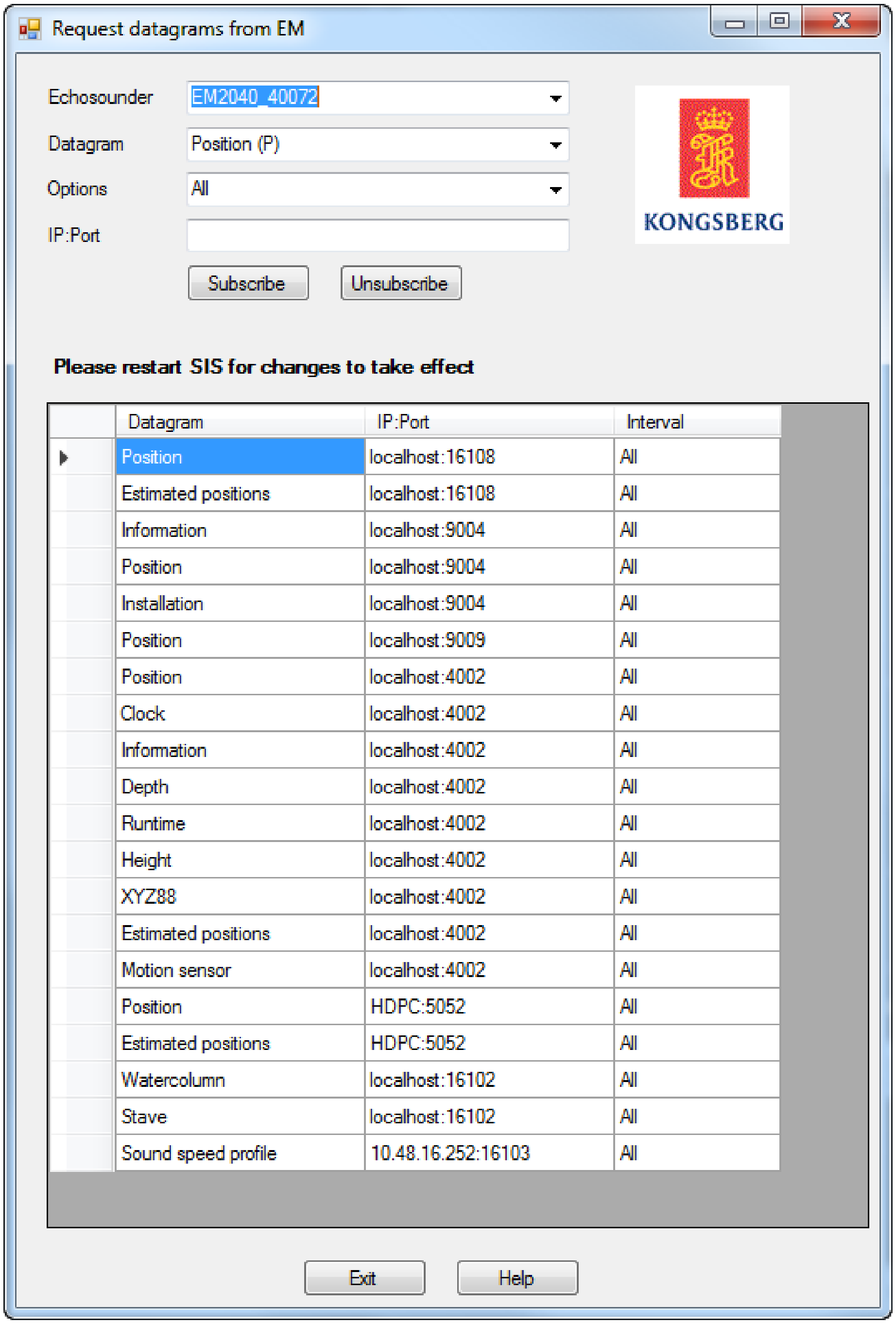

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
PU System Report
System Report.
Path:
D:\sisdata\common\bist
...
Name:

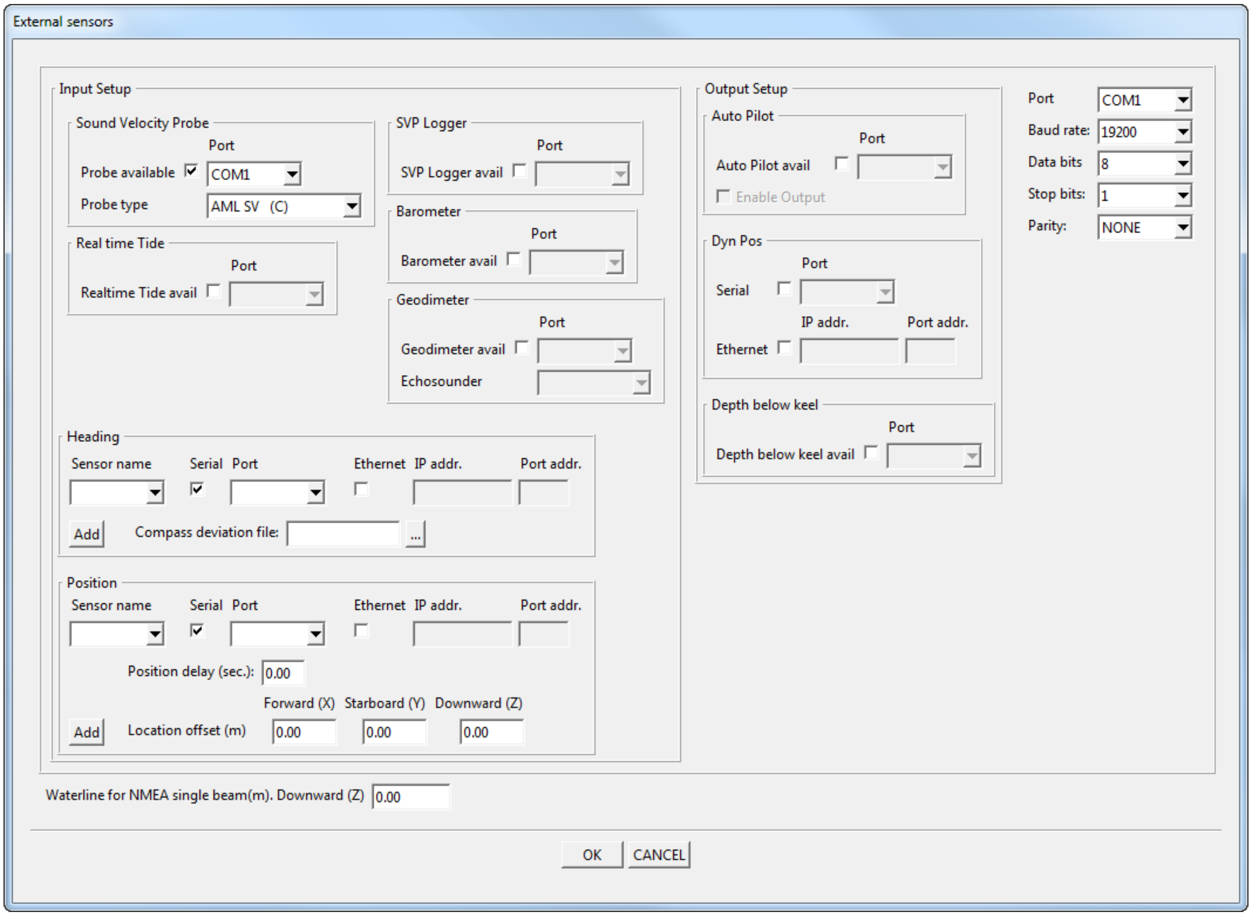

Data Distribution
Data Distribution - MDM 400
Source Port
Source File
Packets
Destination : Port
Destination : Port
Destination : Port
Destination : Port
Destination File
16103
0
10.48.16.251:6001
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1


Set parameters in SIS
Parameters in SIS
Ship
Positions
Turn parameters
Passwords
Display
Logging
Autopilot
Sound speed
Network licence
Error model parameters
APOS
Sensor options
Startup options for system
Projections
Logging control
Parameter Name
Data type
Value
Interval for line counter in sec.
Integer
1800
Put all depths in grid if set to 1, save selected depths if set to 0
Integer
0
Hotkey for logging on/off
String
F2
Hotkey for New line
String
F5
Hotkey for Pinging on/off
String
F10
Enable or disable support for rawdata logger. (0=disable, 1=enable)
Integer
0
Eiva compatible start/stop datagram = 1. SIS default = 0
Integer
0
Water column disk. (Default: Raw data disk.)
String
SVP change should generate new logged line (No=0, Yes=1)
Integer
0
Enable EA raw data logging (No=0, Yes=1)
Integer
1
Gives current data cleaning method, 1-GridEngine, 2-CUBE
Integer
1
Send range and bearing for objects to address (IP:port)
String
Initial watercolumn logging off or on (0=off, 1=on)
Integer
0
Highest approved swath density in percent of requested density (0=no checking, 110-2500=highest approved density in %).
Integer
0
Lowest approved swath density in percent of requested density (0=no checking, 10-90=lowest approved density in %).
Integer
90
Note: Please restart SIS to effectuate.
Exit
Help

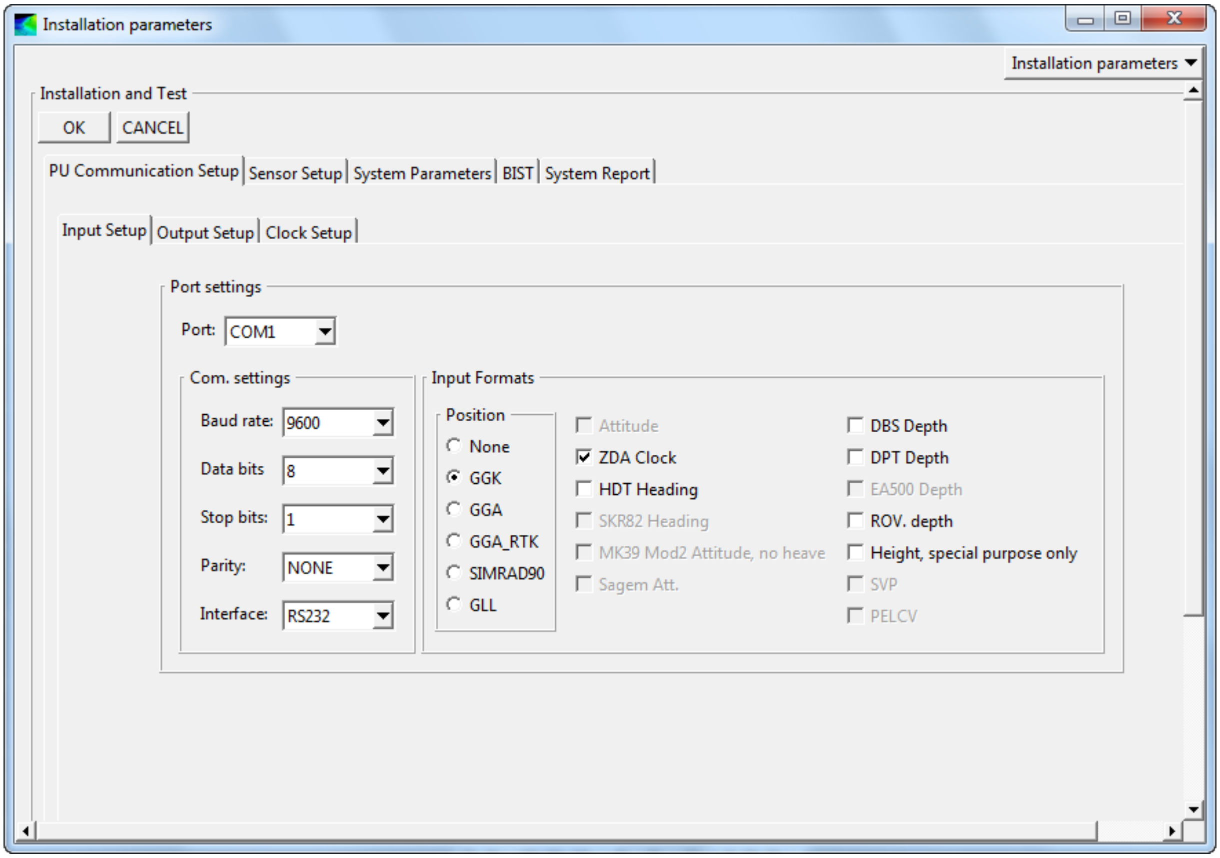

Set parameters in SIS
Parameters in SIS
Ship
Positions
Turn parameters
Passwords
Display
Logging
Autopilot
Sound speed
Network licence
Error model parameters
APOS
Sensor options
Startup options for system
Projections
Sound speed error limits etc.
Parameter Name
Data type
Value
Big difference between sound speed at transducer from profile and probe
Float
2
Too big difference between sound speed at transducer from profile and probe
Float
3
Automatic start of Sound Speed Editor. (0=disabled, 1=enabled)
Integer
0
Max. no. of samples in a sound velocity profile to be used by the old types of echo sounders.
Integer
470
Max. no. of samples in a sound velocity profile to be used by the new types of echo sounders.
Integer
1000
Suppress error report of not extended sound speed profiles to be used immediately (0=No, 1=Yes)
Integer
0
Extend received S00 sound speed profile if necessary (0=No, 1=Yes)
Integer
0
Note: Please restart SIS to effectuate.
Exit
Help

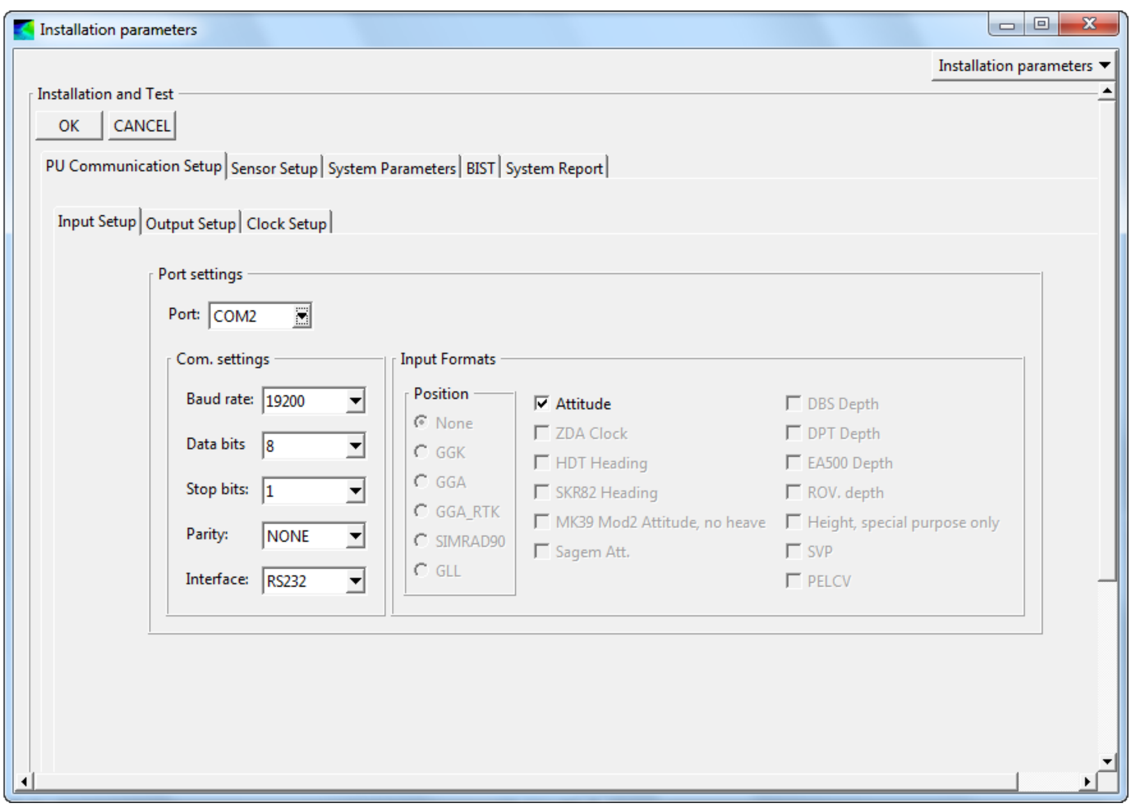

PU sensor status
PU sensor status
PU Sensor input status
COM1 COM2 COM3 COM4 UDP2 UDP5 UDP6
GGA
GGK
P
GGA_RTK
GST
SIMRAD90
Attitude
HM
MK39 Mod2 Attitude, no heave
HDT Heading
SKR82 Heading
ROV. depth
ZDA Clock
Height, special purpose only
DBS Depth
DPT Depth
EA500 Depth
Attitude/Velocity
A
1PPS Clock Synch.
P = active Position sensor
M = active Motion/Attitude sensor
H = active Heading sensor
A = active Attitude/Velocity sensor
Reload

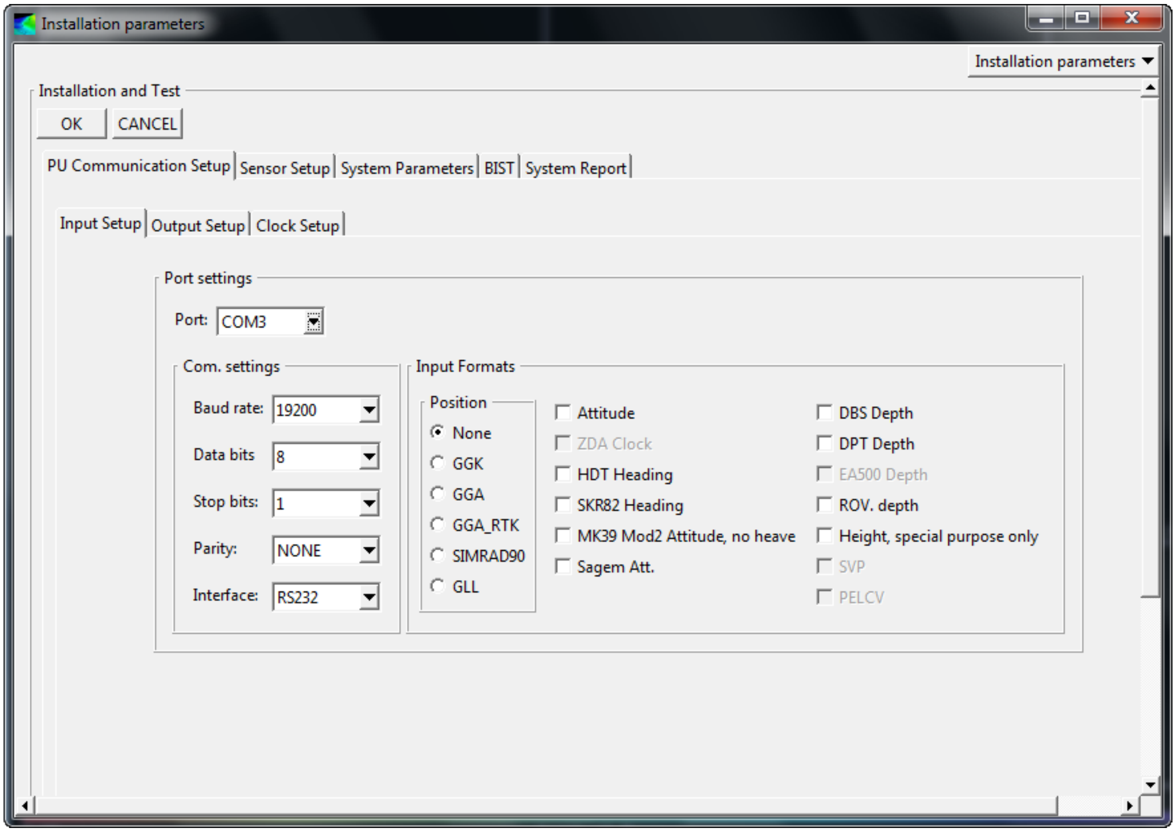

Request datagrams from EM
Echosounder
EM2040_40072
Datagram
Position (P)
Options
All
IP:Port
Subscribe
Unsubscribe
KONGSBERG
Please restart SIS for changes to take effect
Datagram | IP:Port | Interval
Position | localhost:16108 | All
Estimated positions | localhost:16108 | All
Information | localhost:9004 | All
Position | localhost:9004 | All
Installation | localhost:9004 | All
Position | localhost:9009 | All
Position | localhost:4002 | All
Clock | localhost:4002 | All
Information | localhost:4002 | All
Depth | localhost:4002 | All
Runtime | localhost:4002 | All
Height | localhost:4002 | All
XYZ88 | localhost:4002 | All
Estimated positions | localhost:4002 | All
Motion sensor | localhost:4002 | All
Position | HDPC:5052 | All
Estimated positions | HDPC:5052 | All
Watercolumn | localhost:16102 | All
Stave | localhost:16102 | All
Sound speed profile | 10.48.16.252:16103 | All
Exit
Help

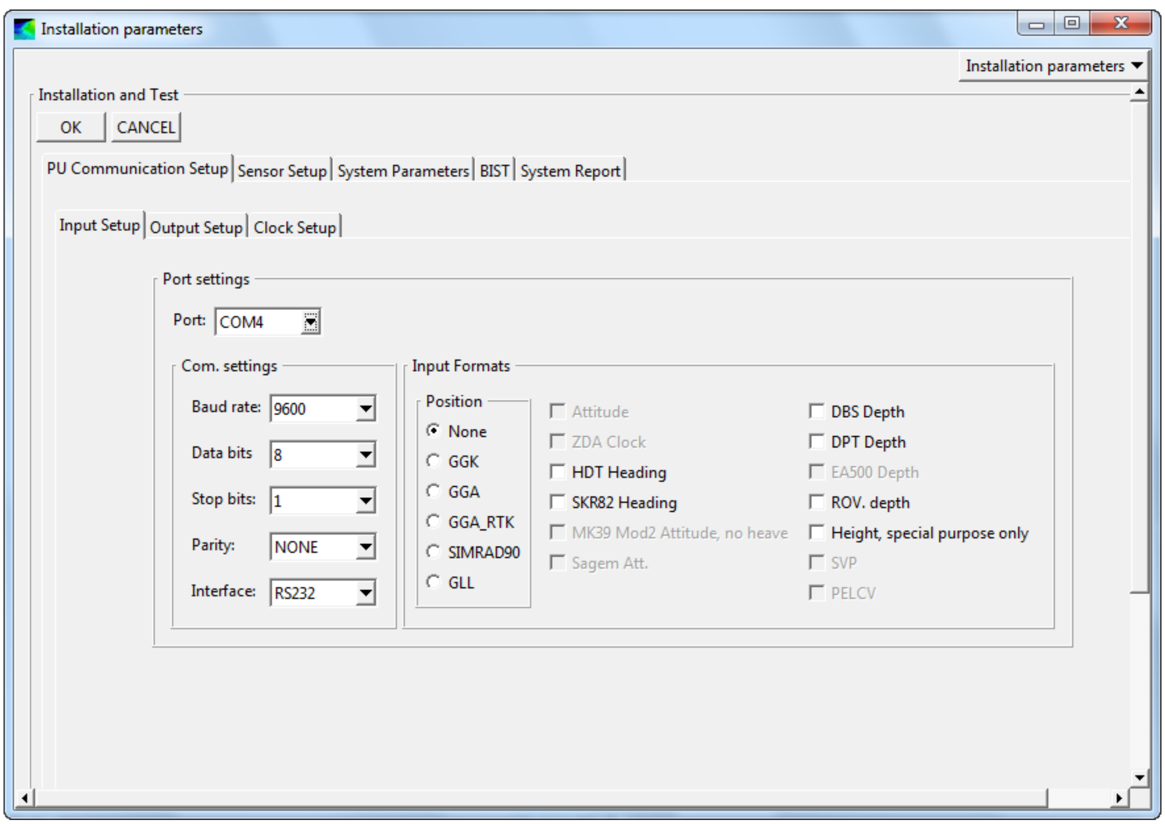

External sensors
Input Setup
Sound Velocity Probe
Port
Probe available
COM1
Probe type
AML SV (C)
SVP Logger
Port
SVP Logger avail
Barometer
Port
Barometer avail
Real time Tide
Port
Realtime Tide avail
Geodimeter
Port
Geodimeter avail
Echosounder
Heading
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Add
Compass deviation file:
...
Position
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Position delay (sec.):
0.00
Forward (X)
Starboard (Y)
Downward (Z)
Add
Location offset (m)
0.00
0.00
0.00
Output Setup
Auto Pilot
Port
Auto Pilot avail
Enable Output
Dyn Pos
Port
Serial
IP addr.
Port addr.
Ethernet
Depth below keel
Port
Depth below keel avail
Port
COM1
Baud rate:
19200
Data bits
8
Stop bits:
1
Parity:
NONE
Waterline for NMEA single beam(m). Downward (Z)
0.00
OK
CANCEL

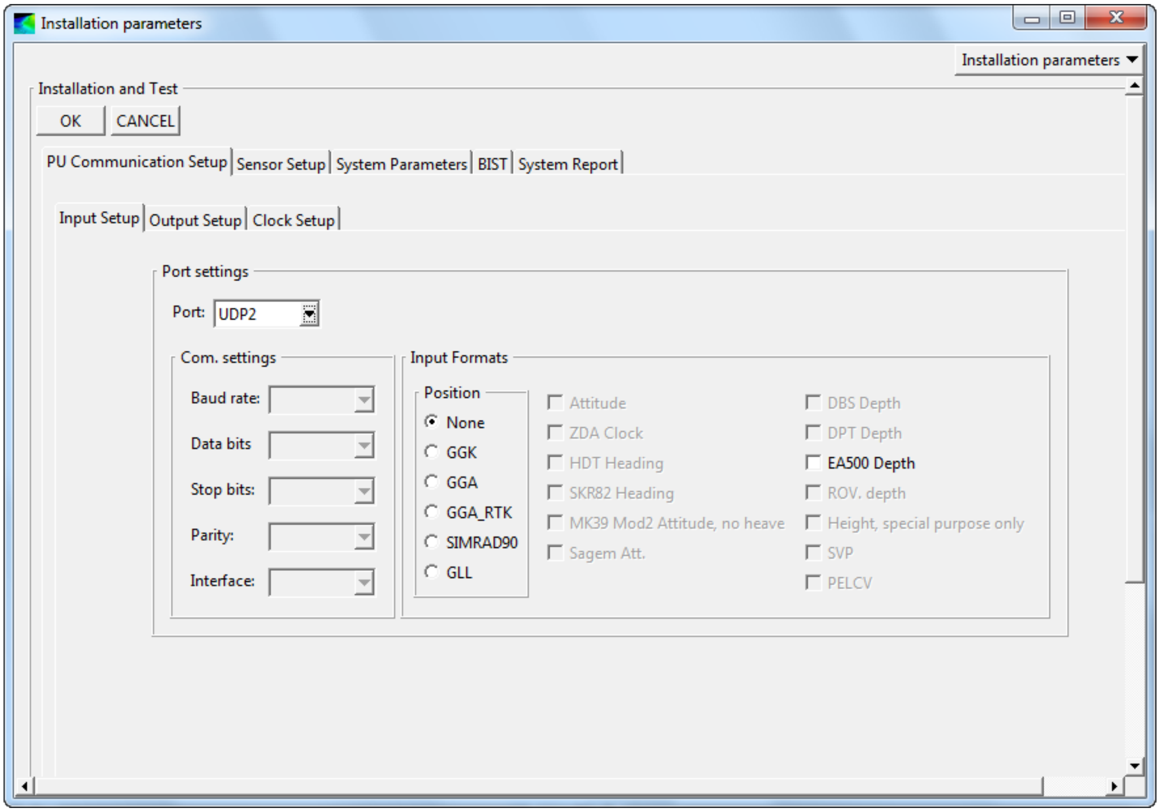
### *10.1.1.2 EM710*

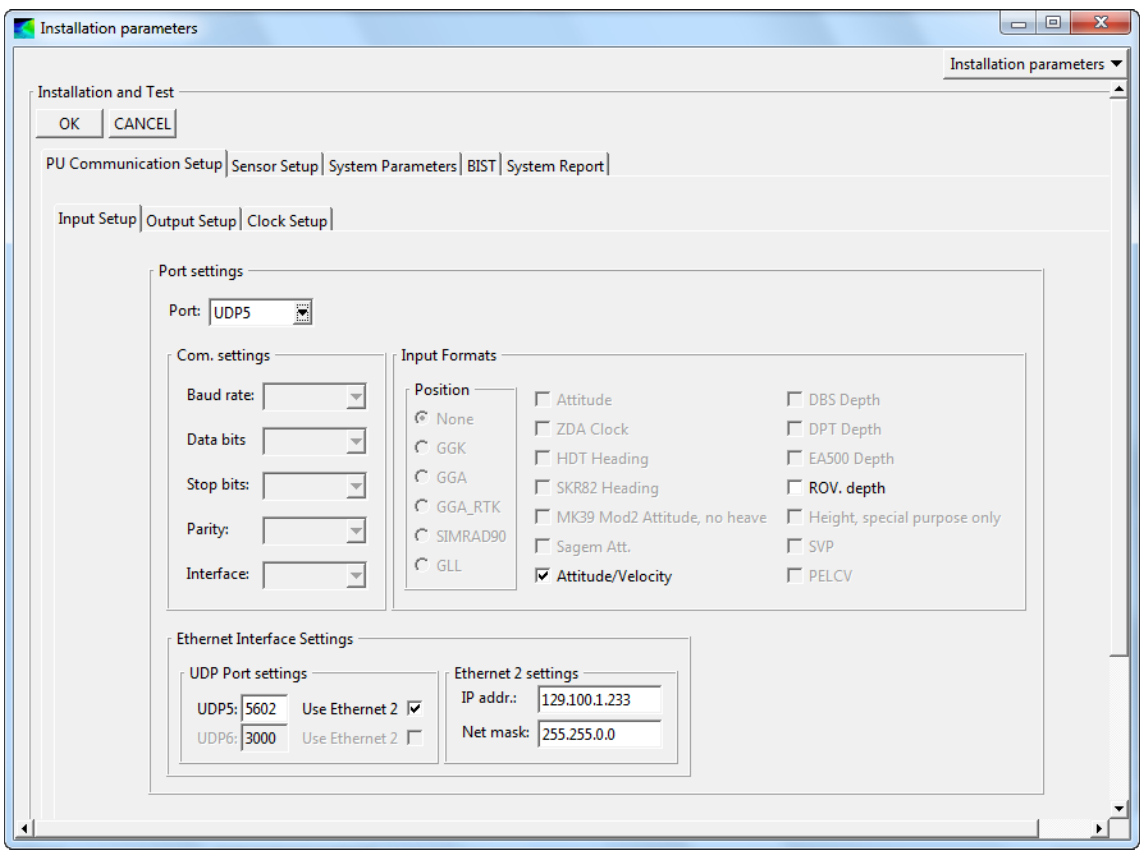

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
COM1
Com. settings
Baud rate:
9600
Data bits
8
Stop bits:
1
Parity:
NONE
Interface:
RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV

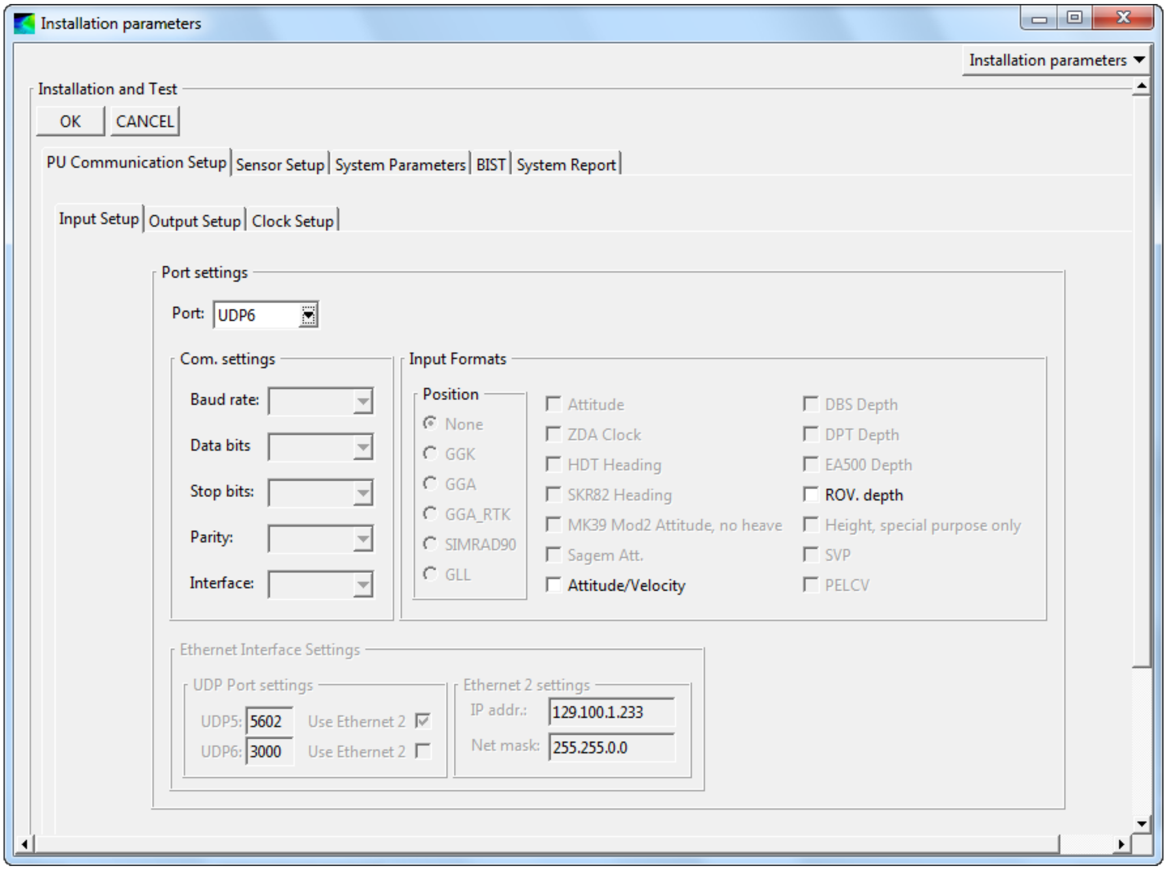

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
COM2
Com. settings
Baud rate:
19200
Data bits
8
Stop bits:
1
Parity:
NONE
Interface:
RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV

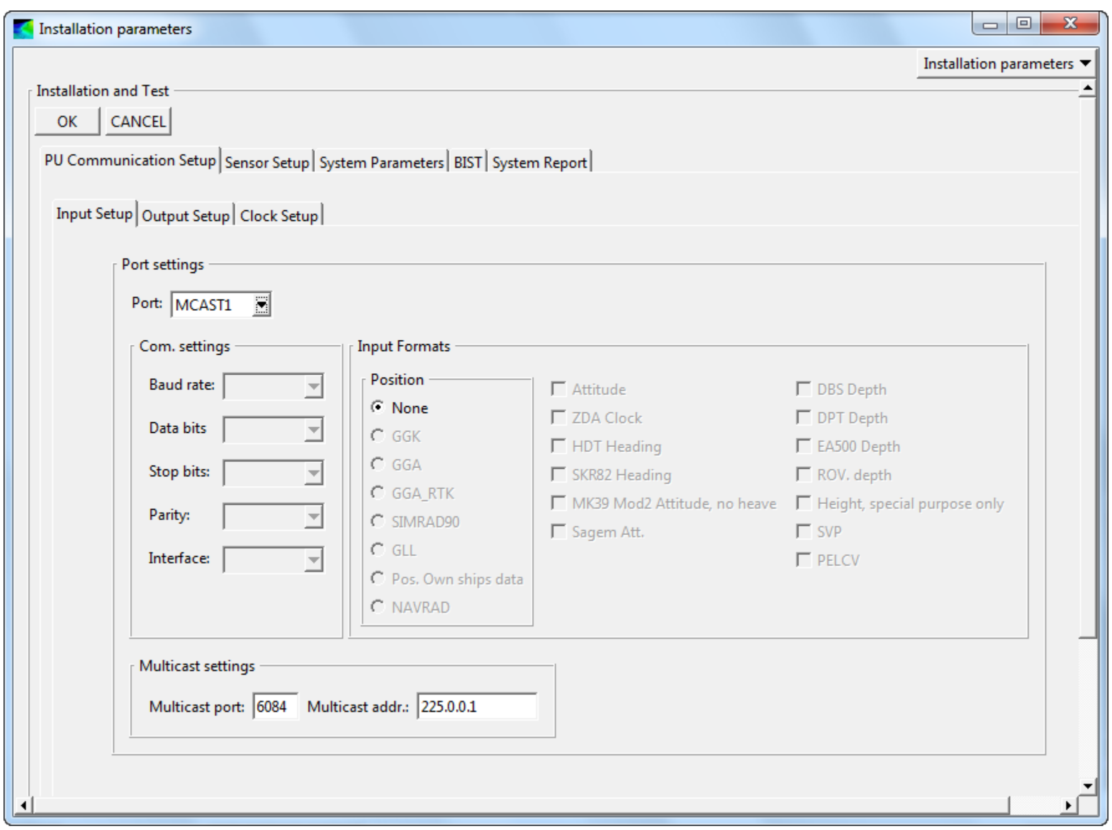

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM3
Com. settings
Baud rate: 19200
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV

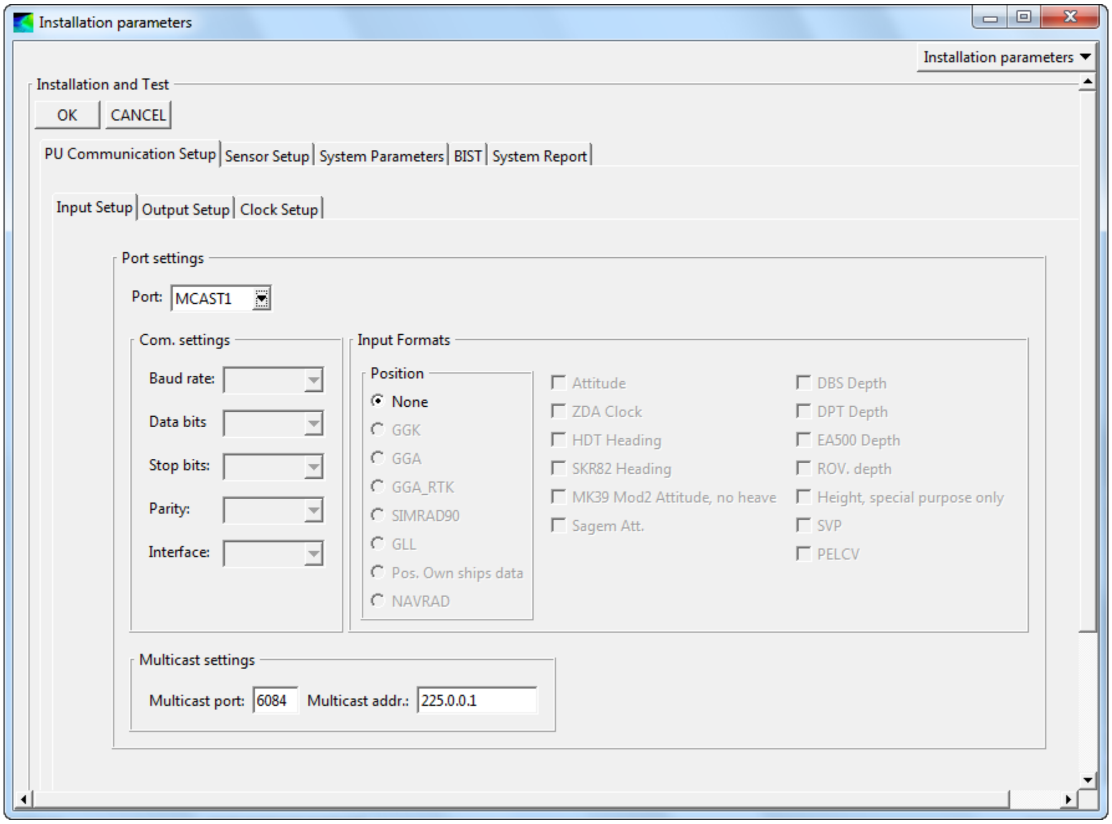

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: COM4
Com. settings
Baud rate: 9600
Data bits 8
Stop bits: 1
Parity: NONE
Interface: RS232
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV

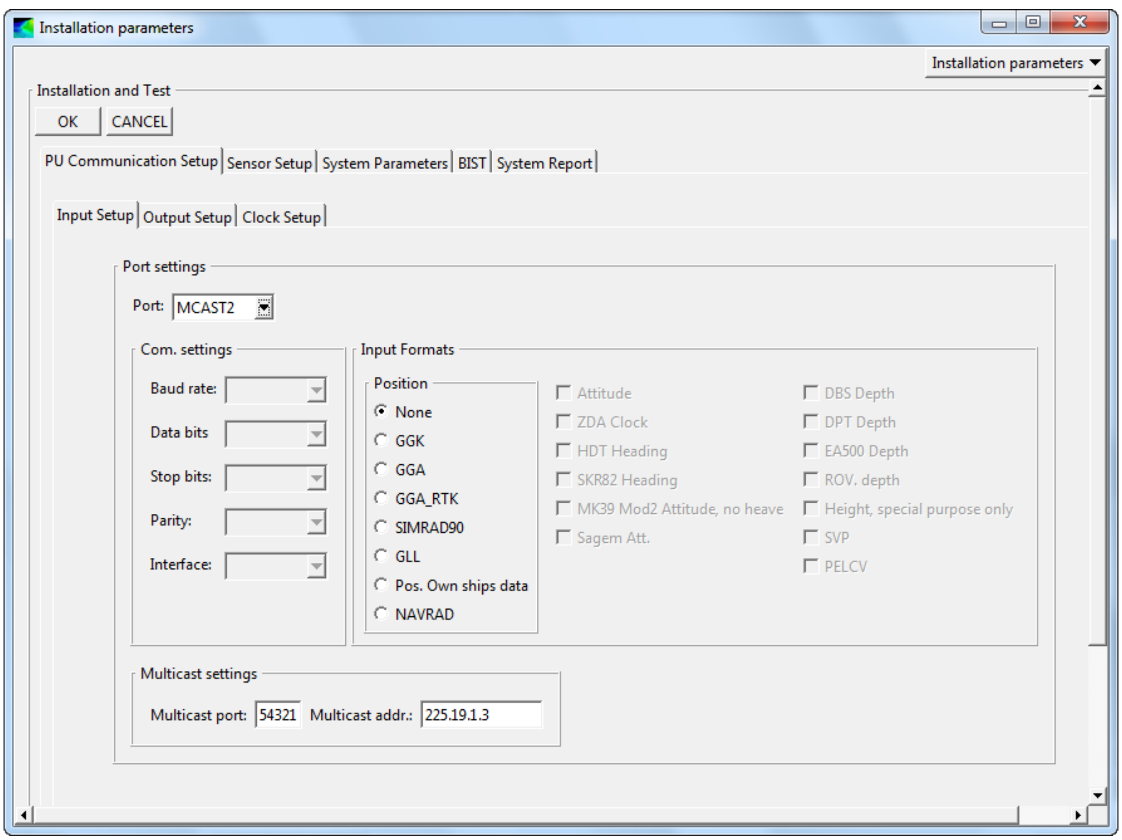

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP2
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV

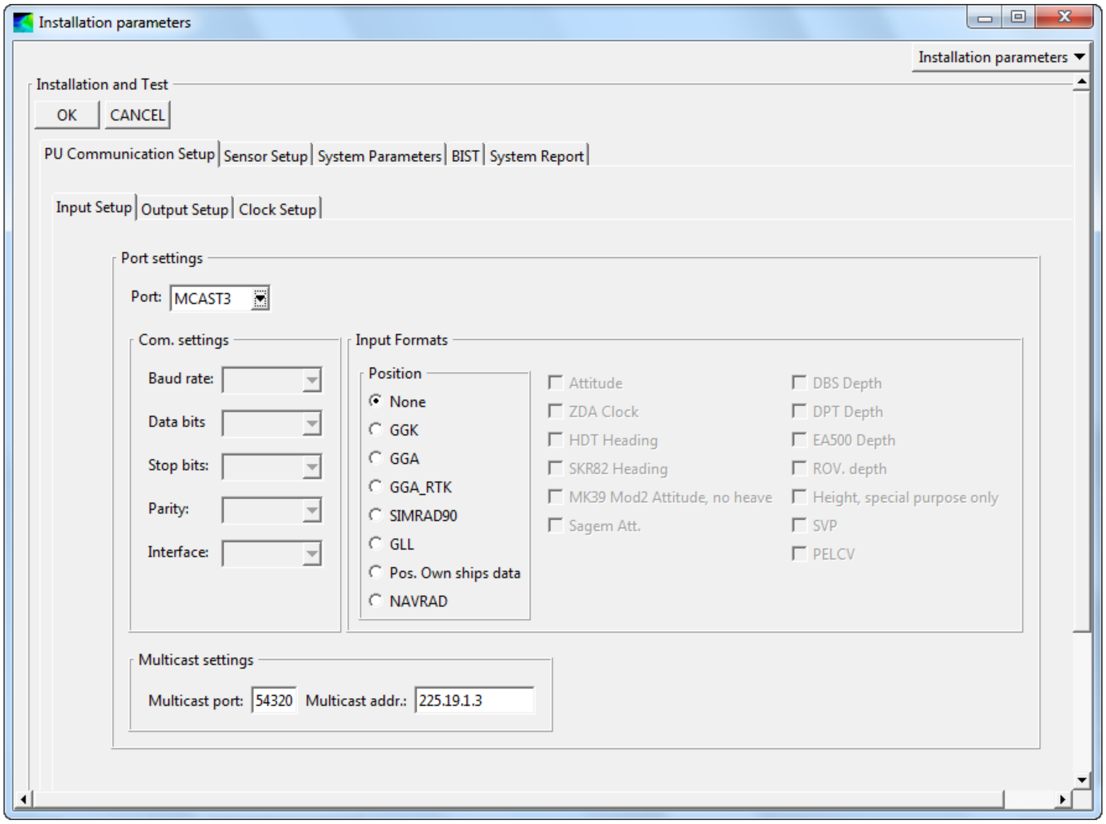

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP5
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
Attitude/Velocity
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Ethernet Interface Settings
UDP Port settings
UDP5: 5602
Use Ethernet 2
UDP6: 3000
Use Ethernet 2
Ethernet 2 settings
IP addr.: 129.100.1.233
Net mask: 255.255.0.0

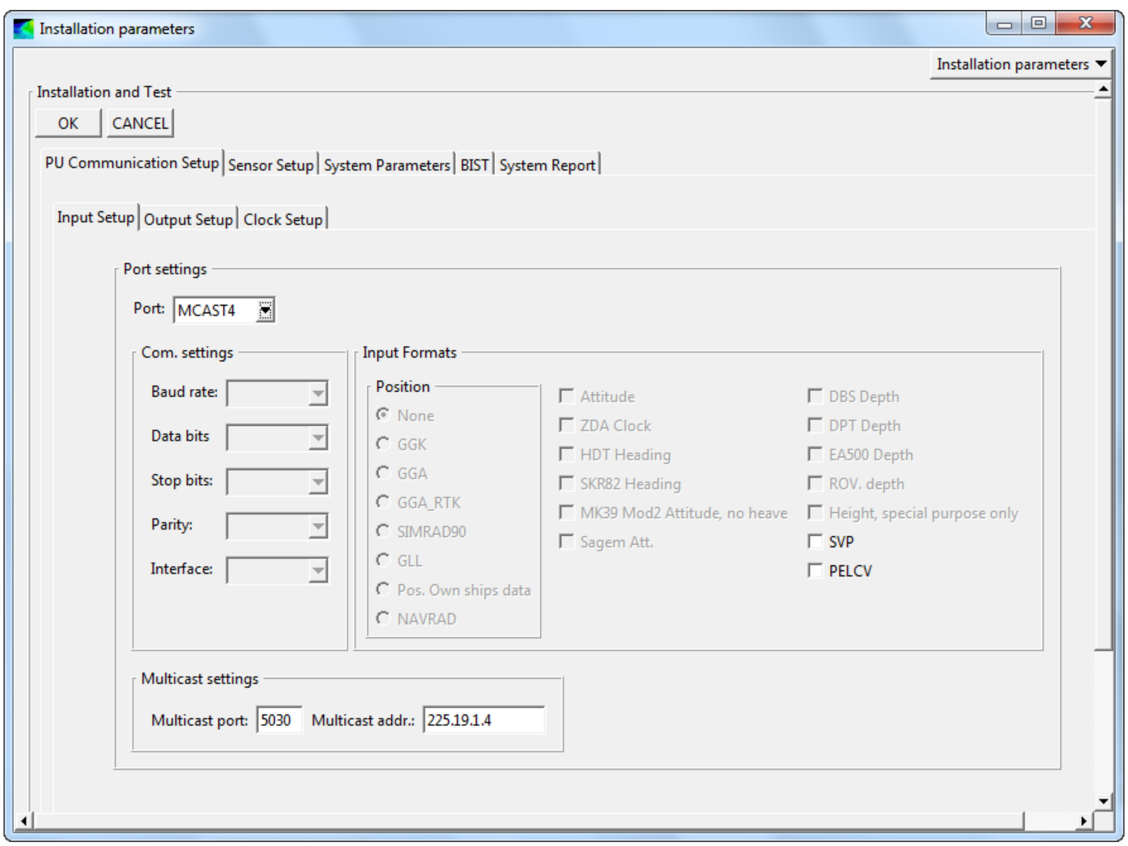

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: UDP6
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
Attitude/Velocity
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Ethernet Interface Settings
UDP Port settings
UDP5: 5602
Use Ethernet 2
UDP6: 3000
Use Ethernet 2
Ethernet 2 settings
IP addr.: 129.100.1.233
Net mask: 255.255.0.0

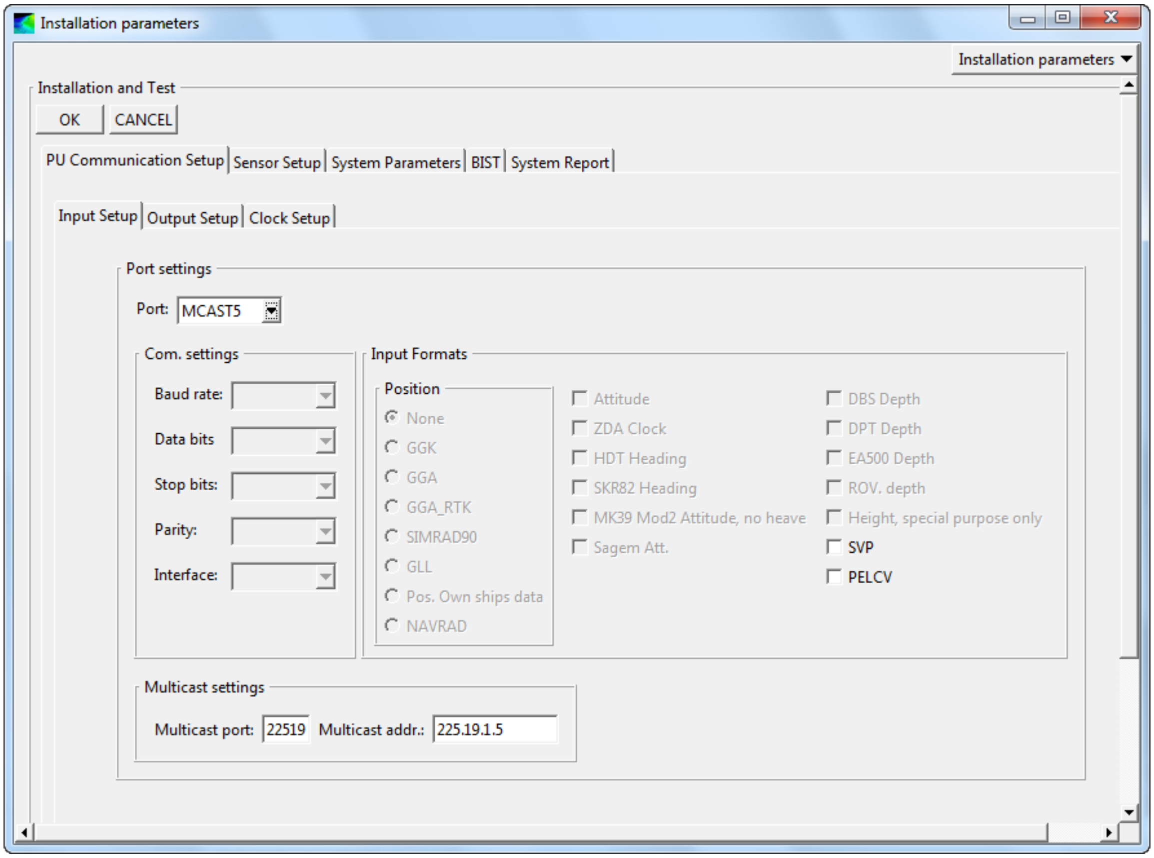

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST1
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port: 6084
Multicast addr.: 225.0.0.1

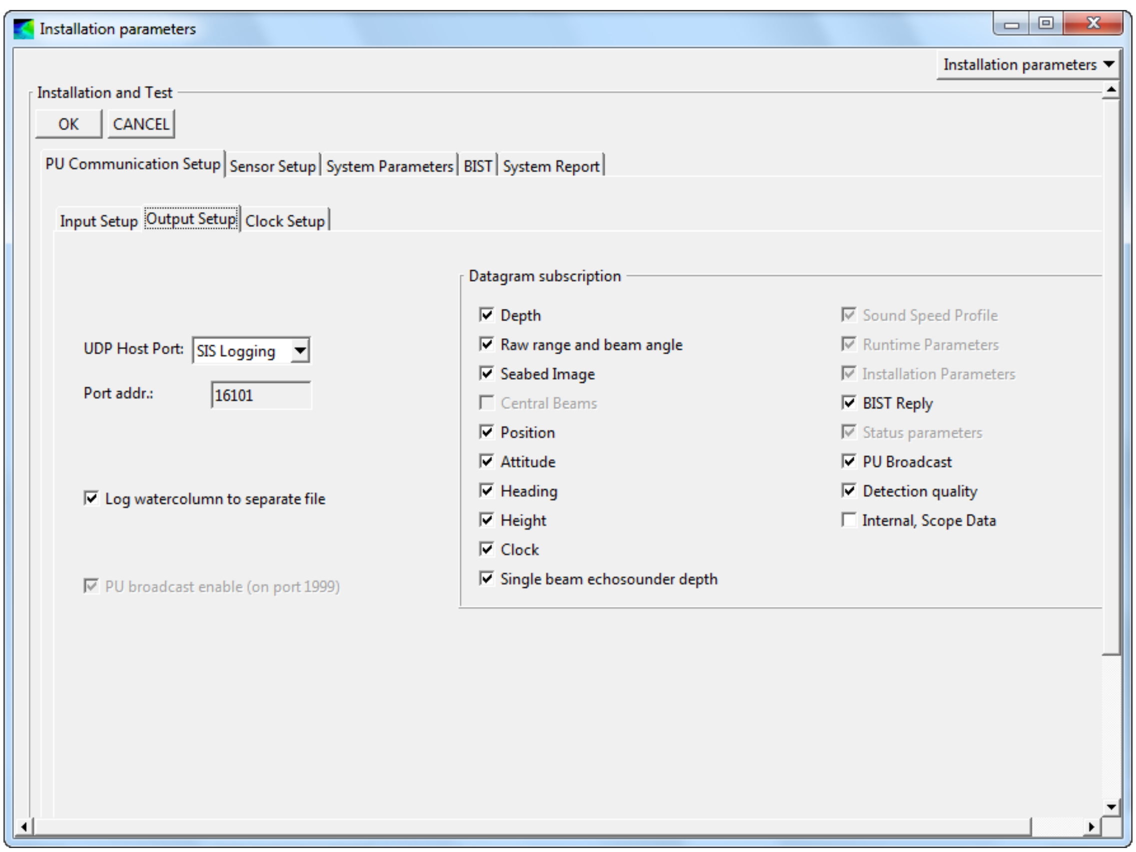

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST1
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port: 6084
Multicast addr.: 225.0.0.1

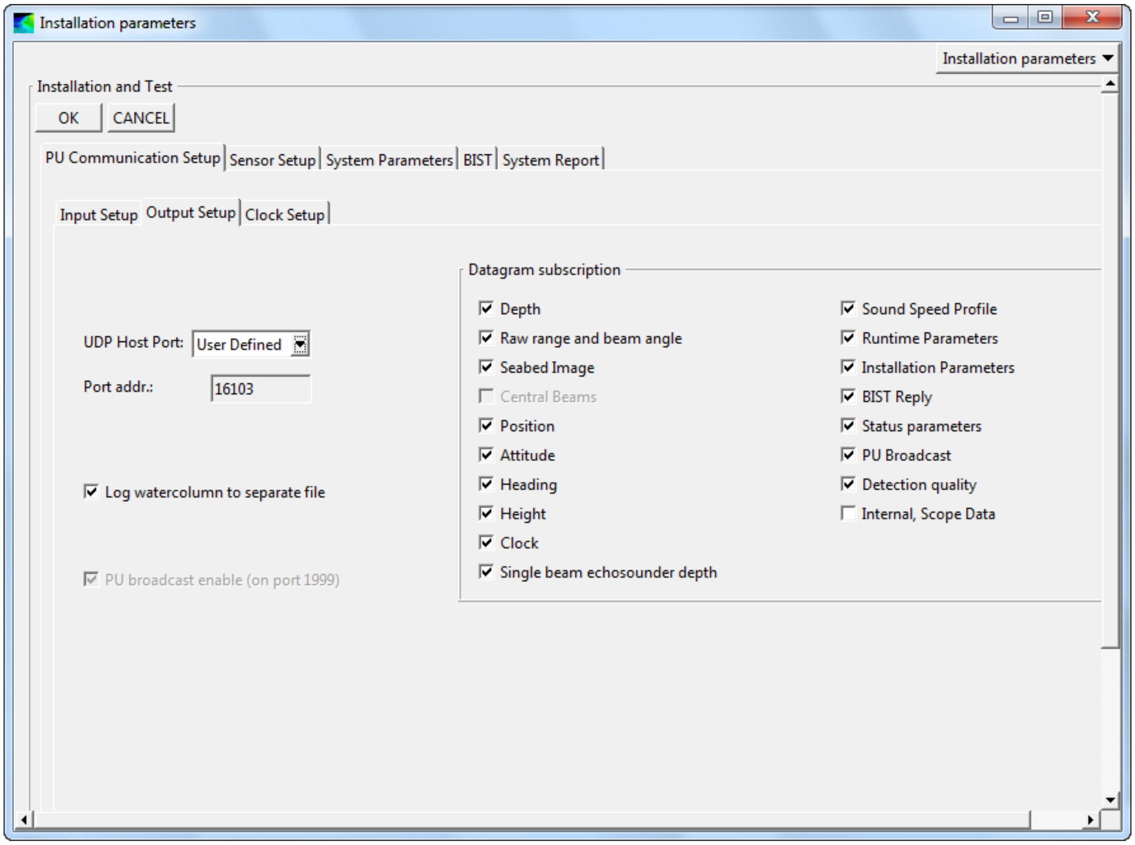

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST2
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port: 54321
Multicast addr.: 225.19.1.3

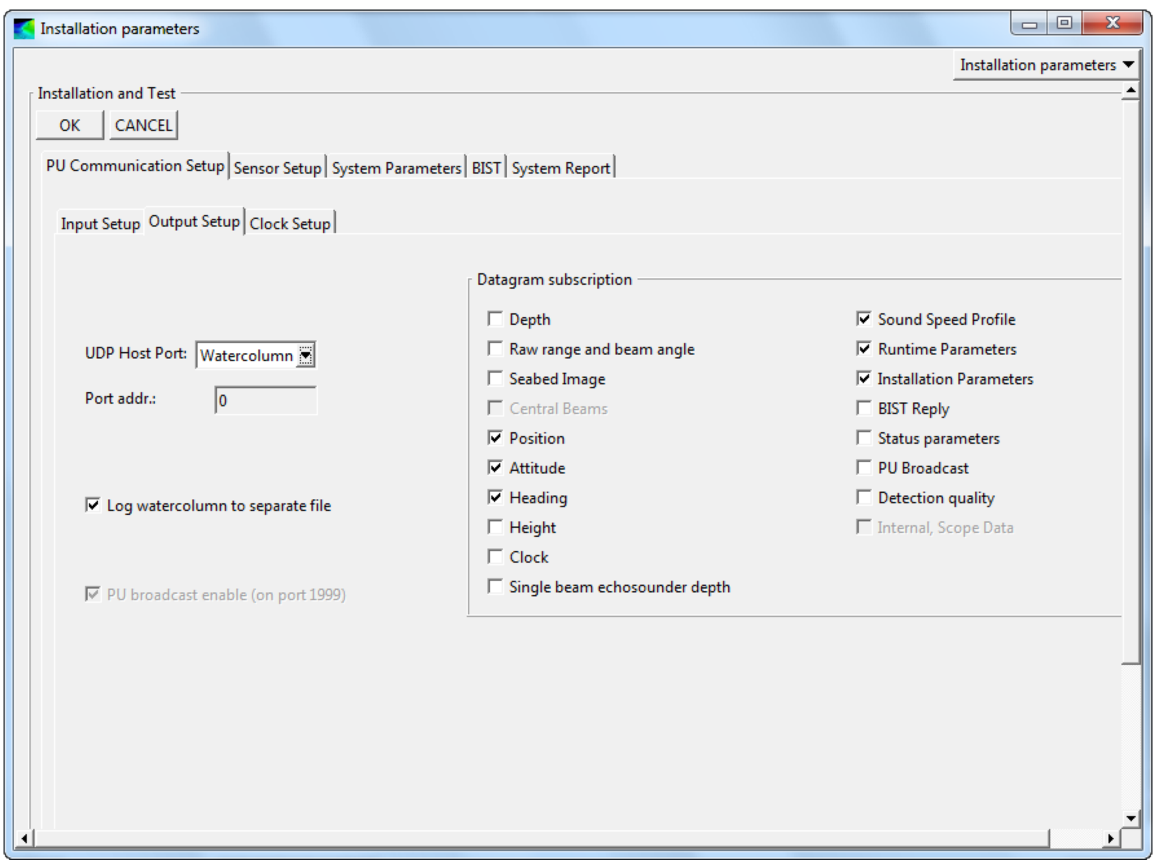

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST3
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port: 54320
Multicast addr.: 225.19.1.3

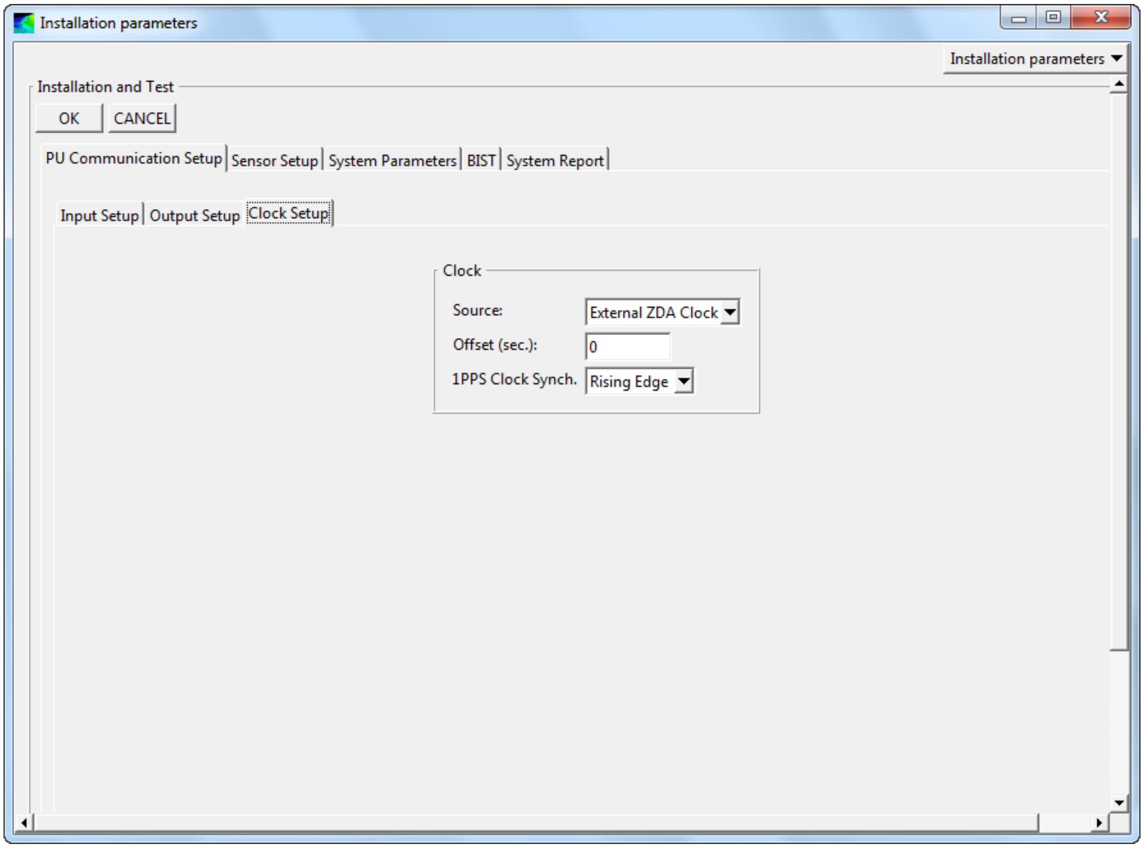

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port: MCAST4
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port: 5030
Multicast addr.: 225.19.1.4

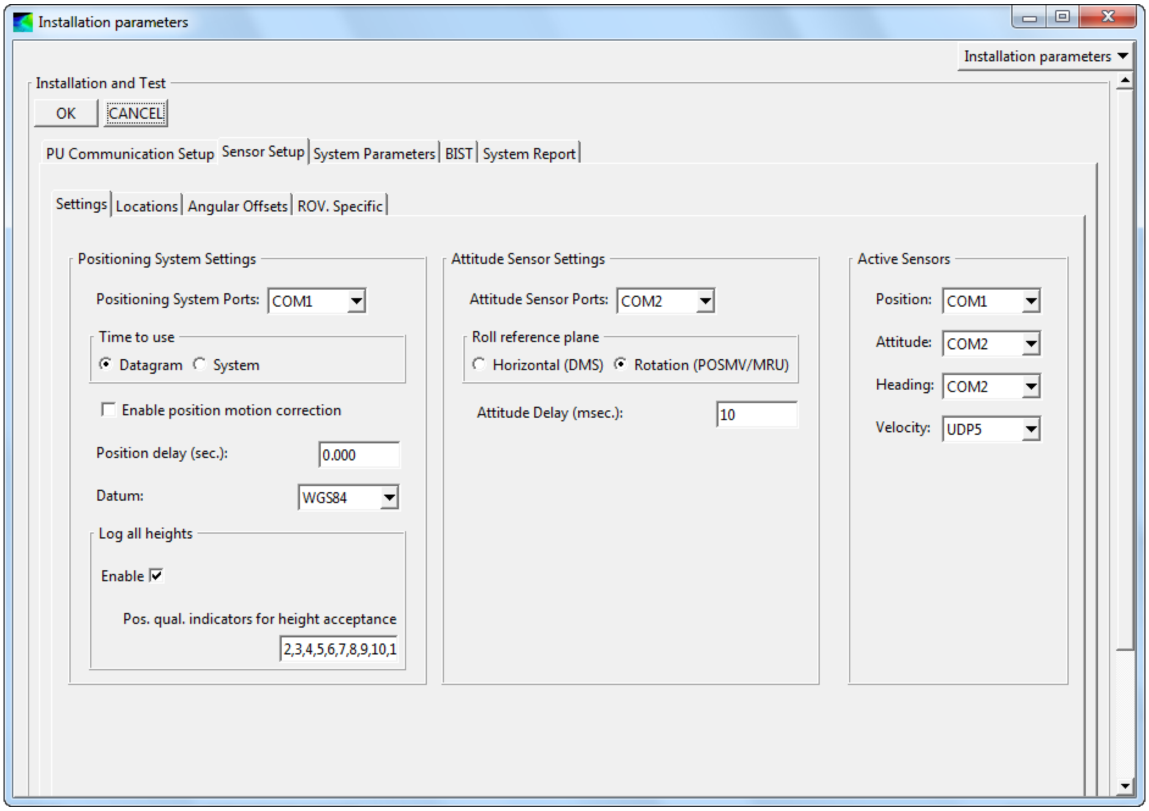

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Port settings
Port:
MCAST5
Com. settings
Baud rate:
Data bits
Stop bits:
Parity:
Interface:
Input Formats
Position
None
GGK
GGA
GGA_RTK
SIMRAD90
GLL
Pos. Own ships data
NAVRAD
Attitude
ZDA Clock
HDT Heading
SKR82 Heading
MK39 Mod2 Attitude, no heave
Sagem Att.
DBS Depth
DPT Depth
EA500 Depth
ROV. depth
Height, special purpose only
SVP
PELCV
Multicast settings
Multicast port:
22519
Multicast addr.:
225.19.1.5

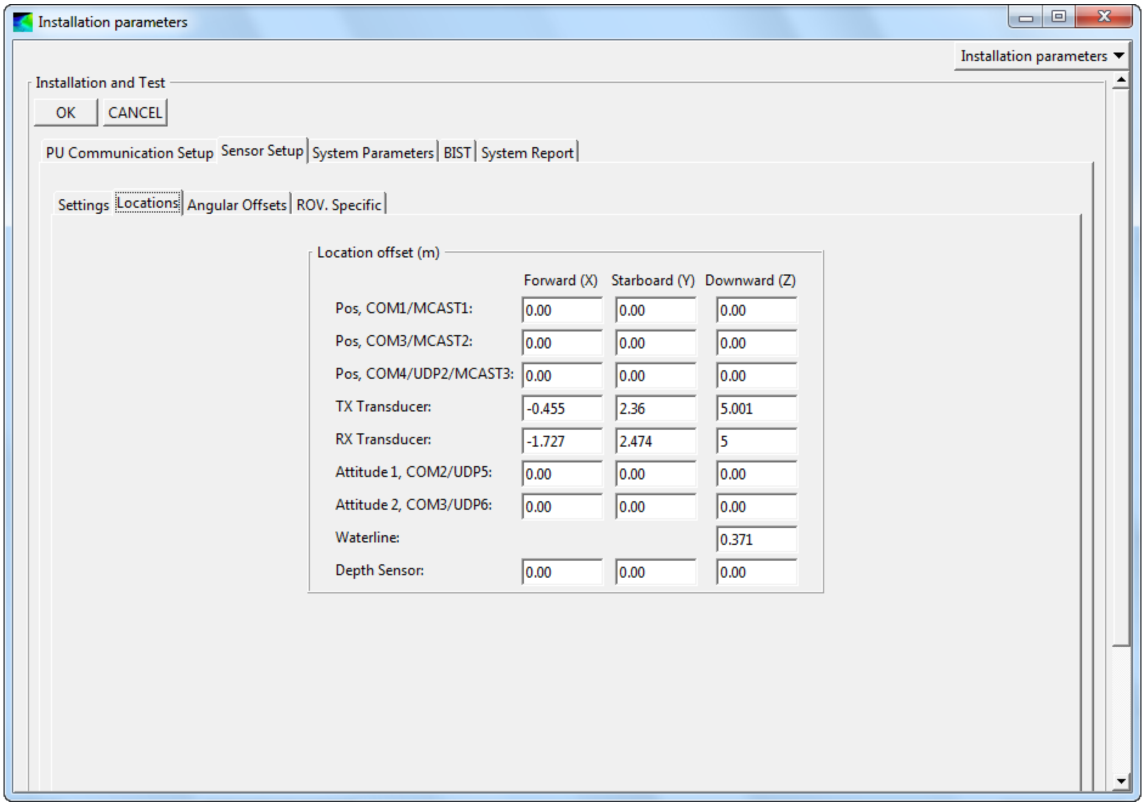

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
SIS Logging
Port addr.:
16101
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

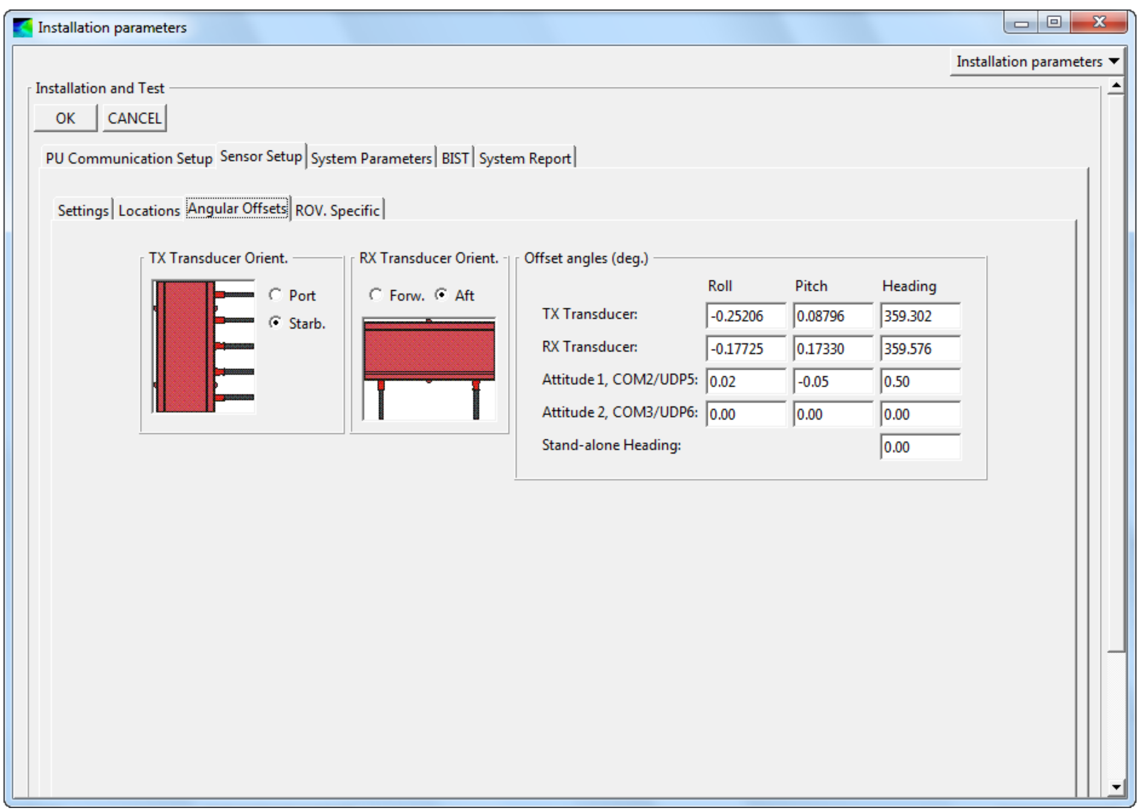

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
User Defined
Port addr.:
16103
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

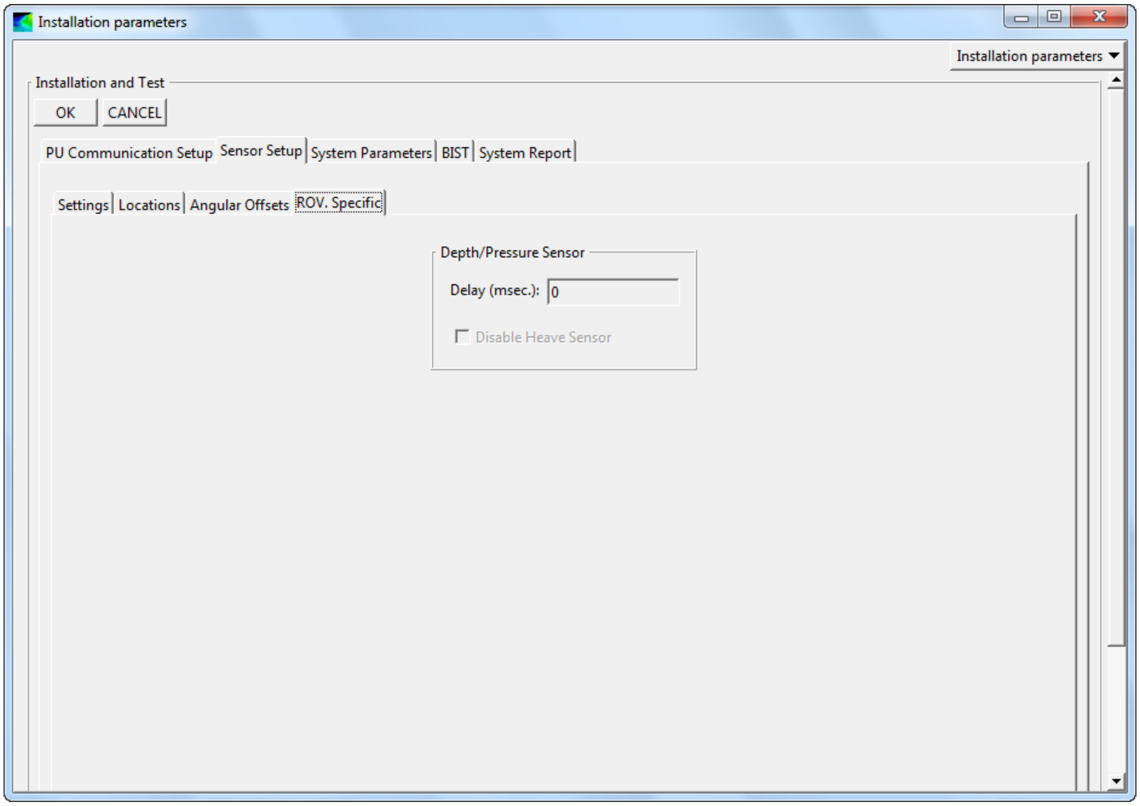

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
UDP Host Port:
Watercolumn
Port addr.:
0
Log watercolumn to separate file
PU broadcast enable (on port 1999)
Datagram subscription
Depth
Raw range and beam angle
Seabed Image
Central Beams
Position
Attitude
Heading
Height
Clock
Single beam echosounder depth
Sound Speed Profile
Runtime Parameters
Installation Parameters
BIST Reply
Status parameters
PU Broadcast
Detection quality
Internal, Scope Data

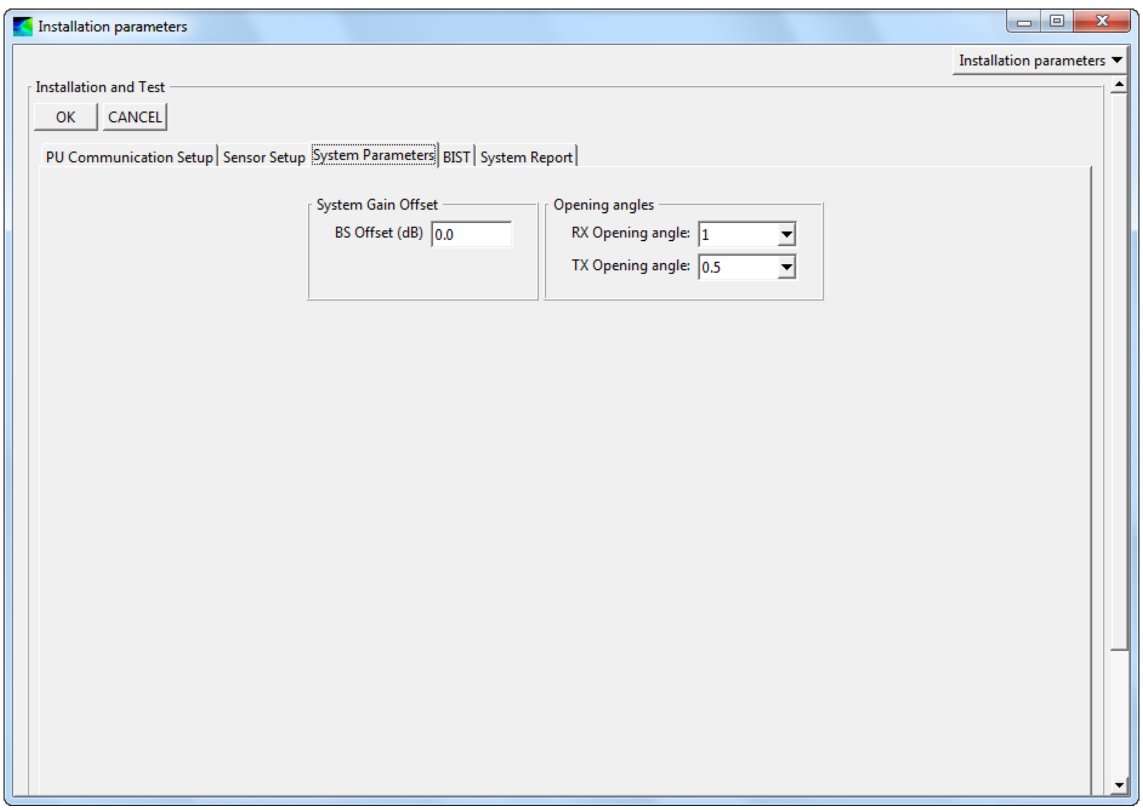

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Input Setup
Output Setup
Clock Setup
Clock
Source:
External ZDA Clock
Offset (sec.):
0
1PPS Clock Synch.
Rising Edge

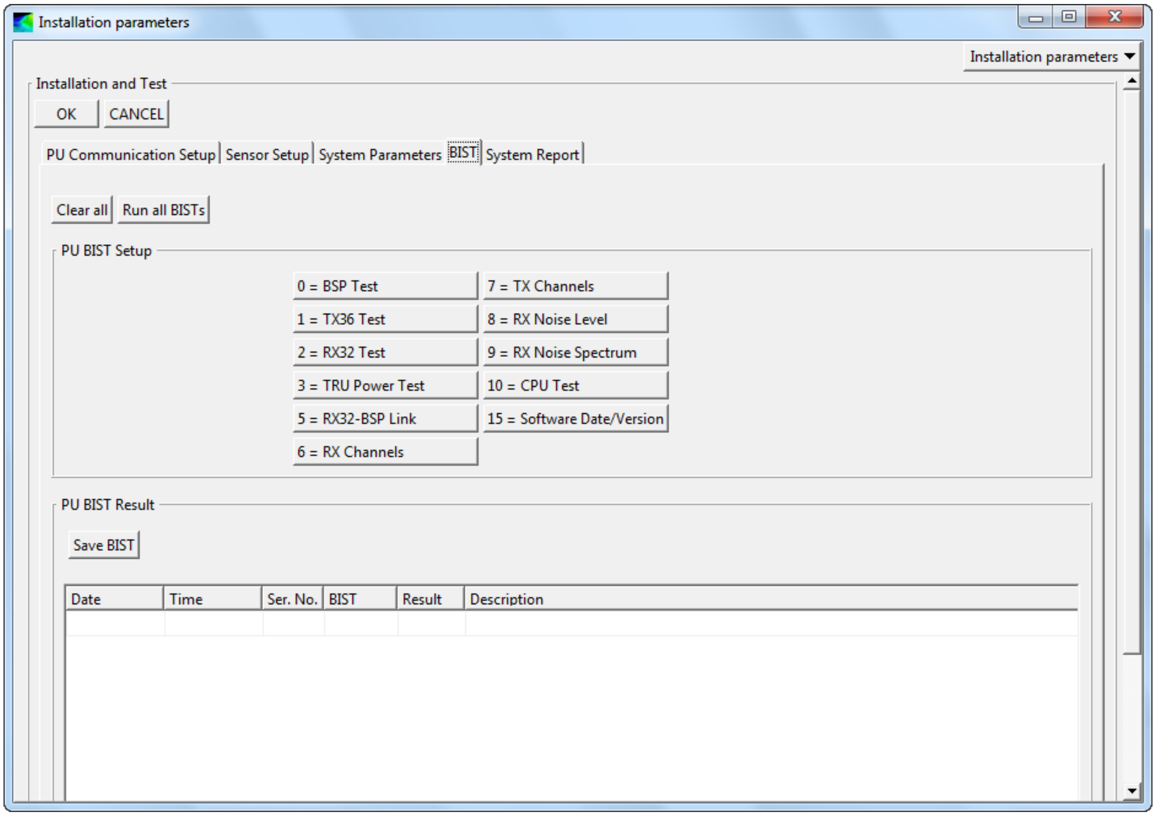

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Positioning System Settings
Positioning System Ports:
COM1
Time to use
Datagram
System
Enable position motion correction
Position delay (sec.):
0.000
Datum:
WGS84
Log all heights
Enable
Pos. qual. indicators for height acceptance
2,3,4,5,6,7,8,9,10,1
Attitude Sensor Settings
Attitude Sensor Ports:
COM2
Roll reference plane
Horizontal (DMS)
Rotation (POSMV/MRU)
Attitude Delay (msec.):
10
Active Sensors
Position:
COM1
Attitude:
COM2
Heading:
COM2
Velocity:
UDP5

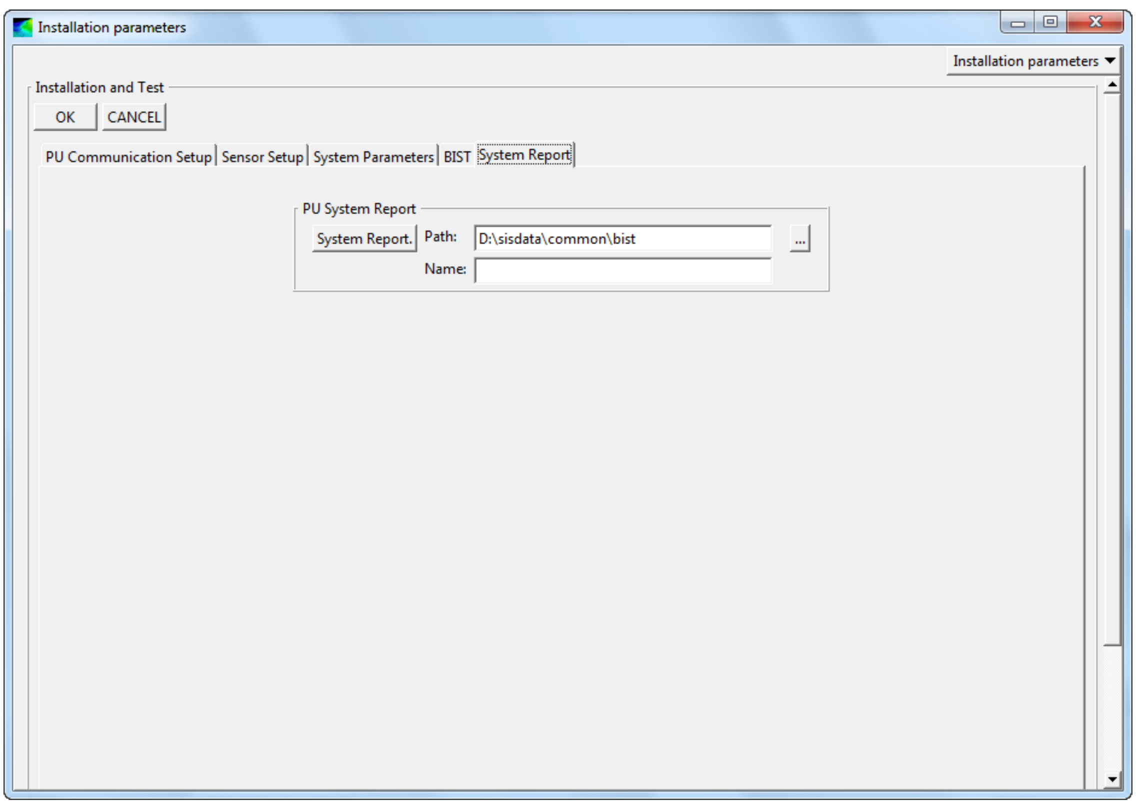

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Location offset (m)
Forward (X)
Starboard (Y)
Downward (Z)
Pos, COM1/MCAST1: 0.00 0.00 0.00
Pos, COM3/MCAST2: 0.00 0.00 0.00
Pos, COM4/UDP2/MCAST3: 0.00 0.00 0.00
TX Transducer: -0.455 2.36 5.001
RX Transducer: -1.727 2.474 5
Attitude 1, COM2/UDP5: 0.00 0.00 0.00
Attitude 2, COM3/UDP6: 0.00 0.00 0.00
Waterline: 0.371
Depth Sensor: 0.00 0.00 0.00

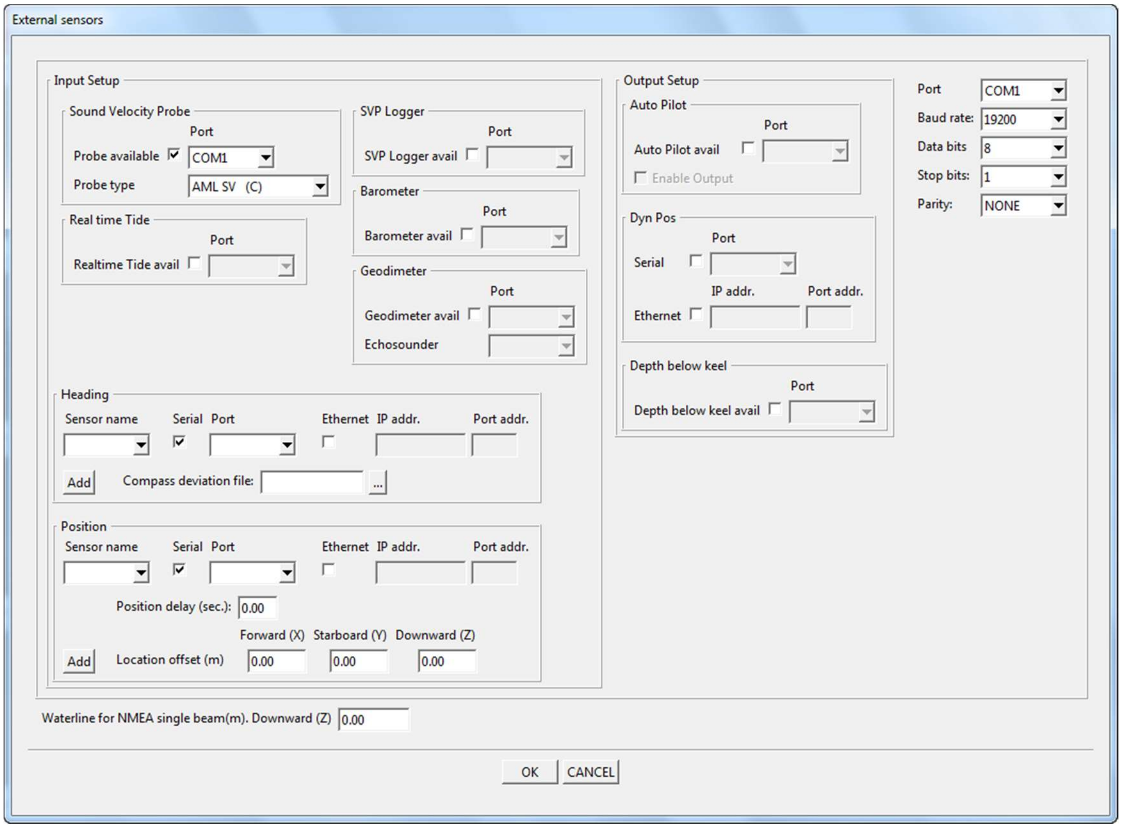

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
TX Transducer Orient.
Port
Starb.
RX Transducer Orient.
Forw.
Aft
Offset angles (deg.)
Roll
Pitch
Heading
TX Transducer: -0.25206 0.08796 359.302
RX Transducer: -0.17725 0.17330 359.576
Attitude 1, COM2/UDP5: 0.02 -0.05 0.50
Attitude 2, COM3/UDP6: 0.00 0.00 0.00
Stand-alone Heading: 0.00

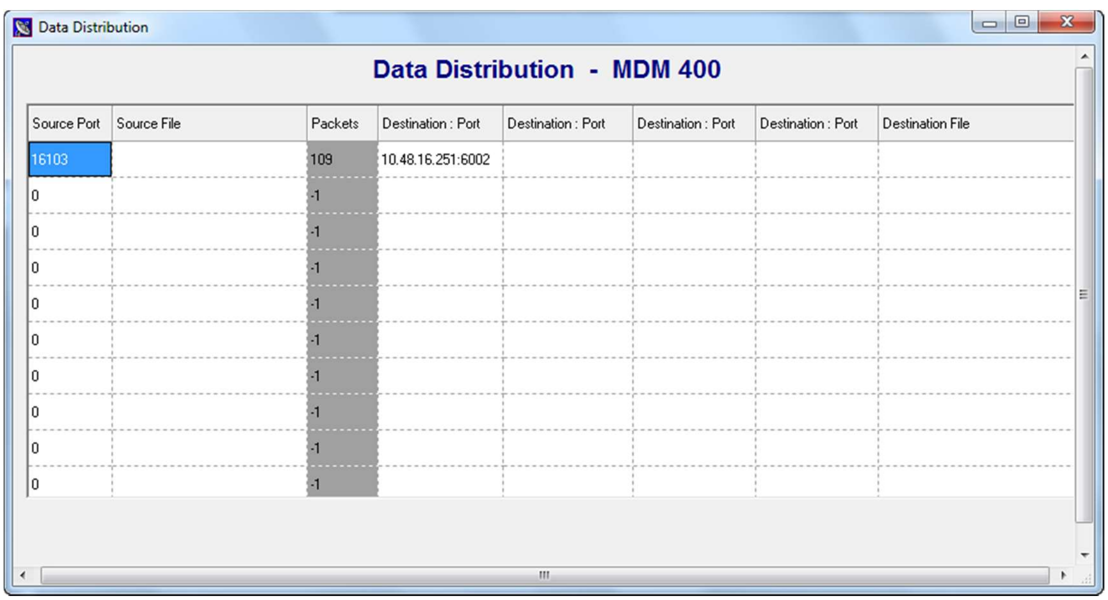

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
Depth/Pressure Sensor
Delay (msec.):
0
Disable Heave Sensor

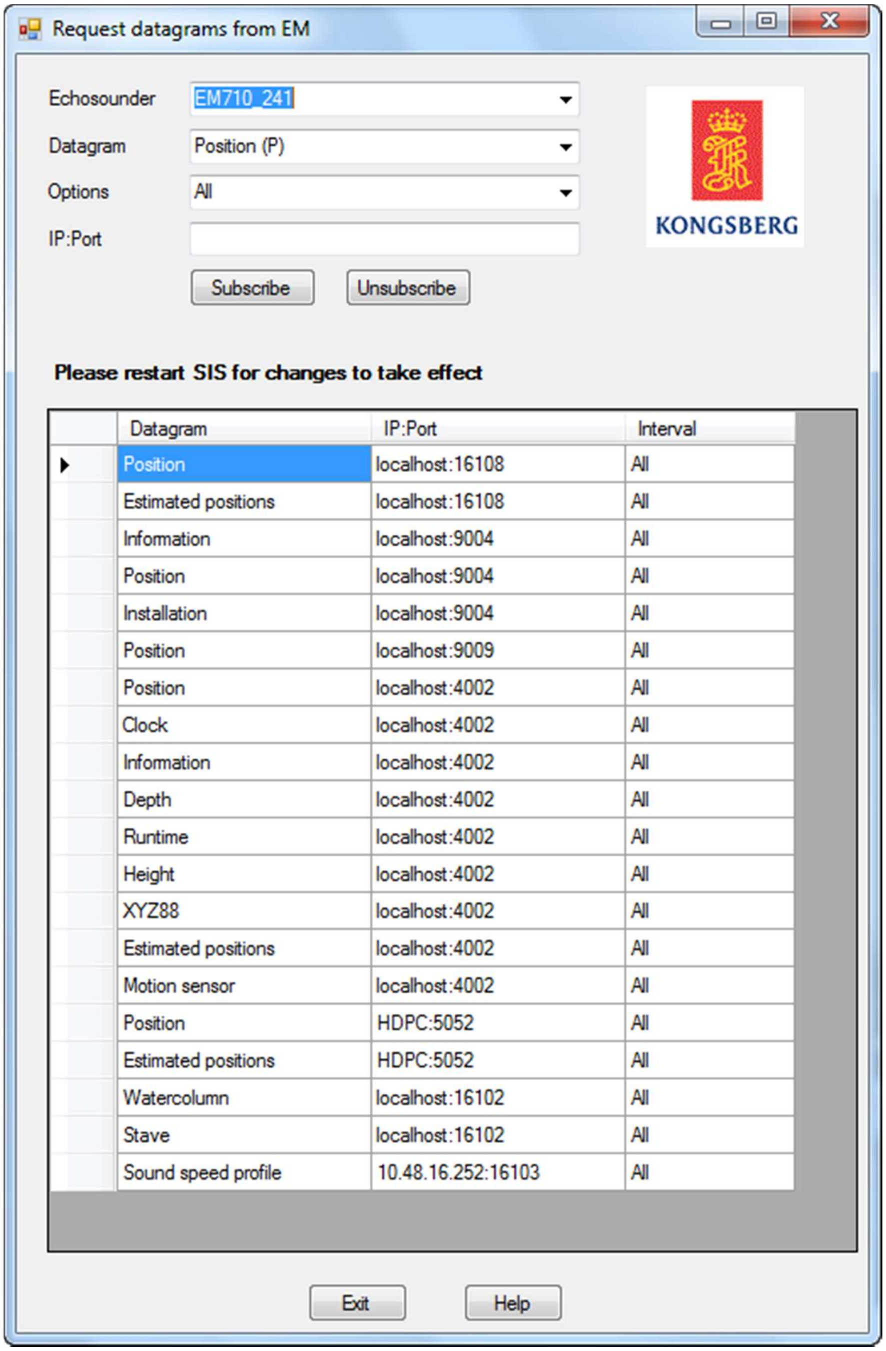

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
System Gain Offset
BS Offset (dB)
0.0
Opening angles
RX Opening angle:
1
TX Opening angle:
0.5


Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Clear all
Run all BISTs
PU BIST Setup
0 = BSP Test
7 = TX Channels
1 = TX36 Test
8 = RX Noise Level
2 = RX32 Test
9 = RX Noise Spectrum
3 = TRU Power Test
10 = CPU Test
5 = RX32-BSP Link
15 = Software Date/Version
6 = RX Channels
PU BIST Result
Save BIST
Date
Time
Ser. No.
BIST
Result
Description

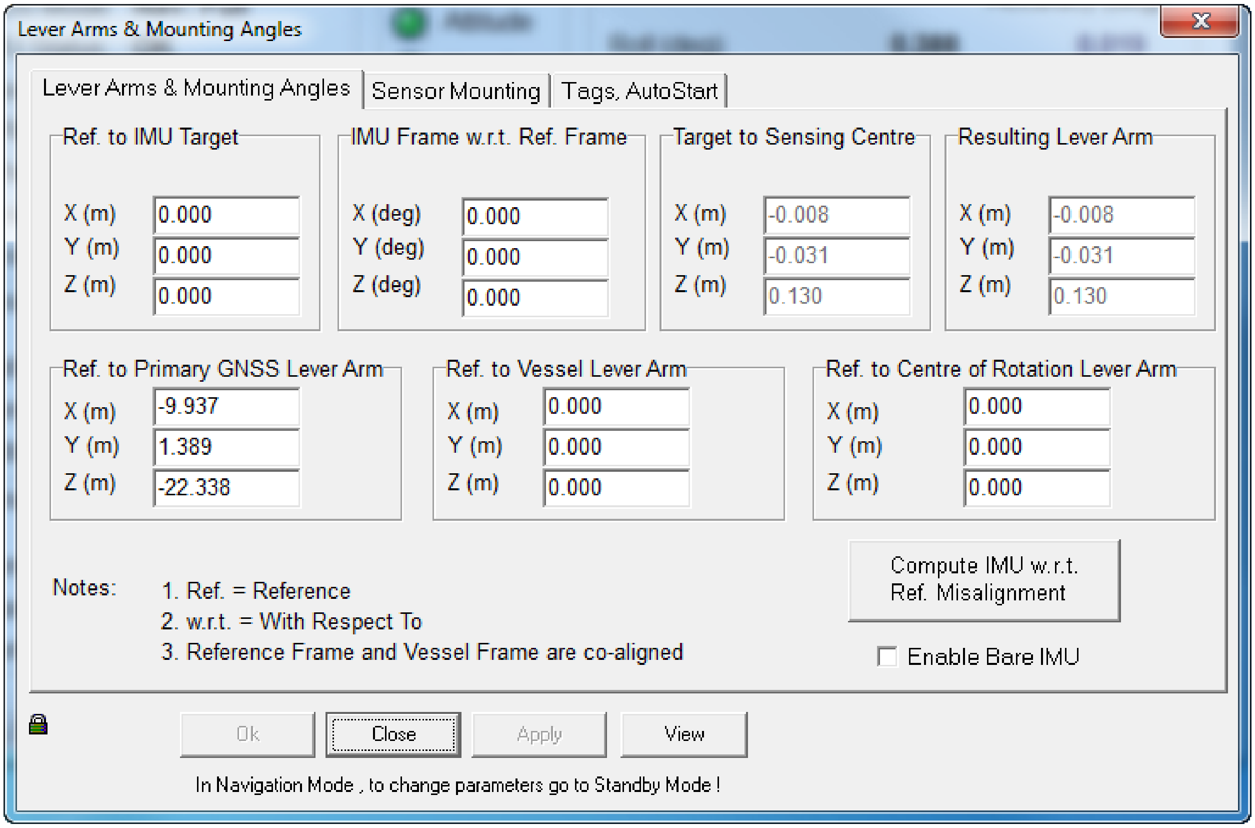

Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
PU System Report
System Report.
Path:
D:\sisdata\common\bist
...
Name:

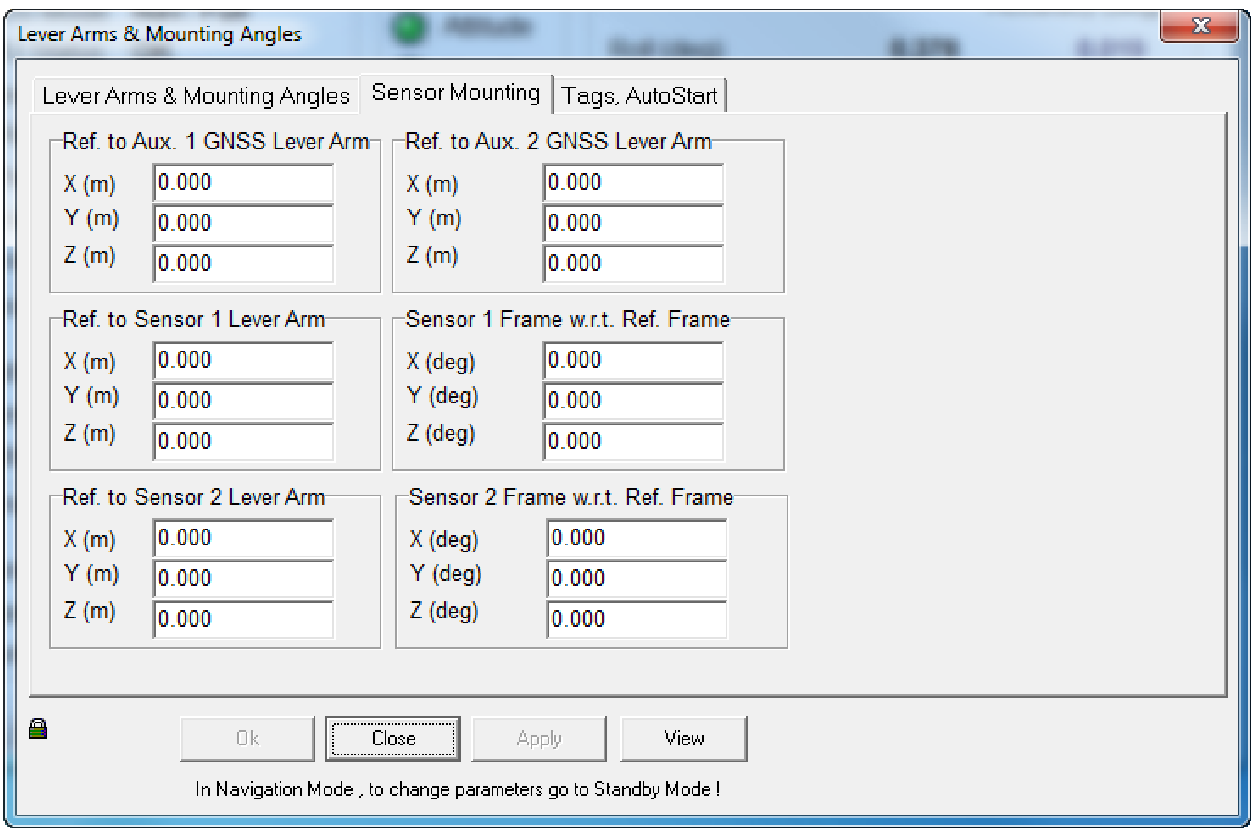

External sensors
Input Setup
Sound Velocity Probe
Port
Probe available
COM1
Probe type
AML SV (C)
SVP Logger
Port
SVP Logger avail
Barometer
Port
Barometer avail
Geodimeter
Port
Geodimeter avail
Echosounder
Real time Tide
Port
Realtime Tide avail
Heading
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Add
Compass deviation file:
Position
Sensor name
Serial
Port
Ethernet
IP addr.
Port addr.
Position delay (sec.):
0.00
Forward (X)
Starboard (Y)
Downward (Z)
Add
Location offset (m)
0.00
0.00
0.00
Output Setup
Auto Pilot
Port
Auto Pilot avail
Enable Output
Dyn Pos
Port
Serial
IP addr.
Port addr.
Ethernet
Depth below keel
Port
Depth below keel avail
Port
COM1
Baud rate:
19200
Data bits
8
Stop bits:
1
Parity:
NONE
Waterline for NMEA single beam(m). Downward (Z)
0.00
OK
CANCEL

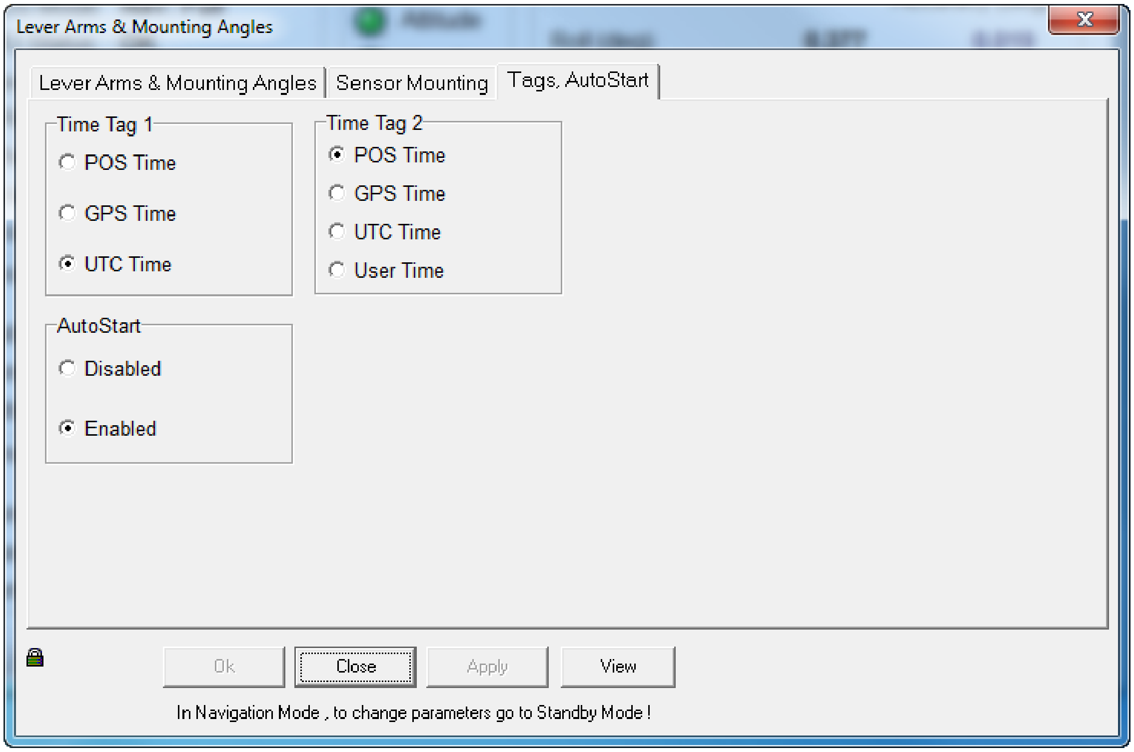

Data Distribution
Data Distribution - MDM 400
Source Port
Source File
Packets
Destination : Port
Destination : Port
Destination : Port
Destination : Port
Destination File
16103
109
10.48.16.251:6002
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1
0
-1

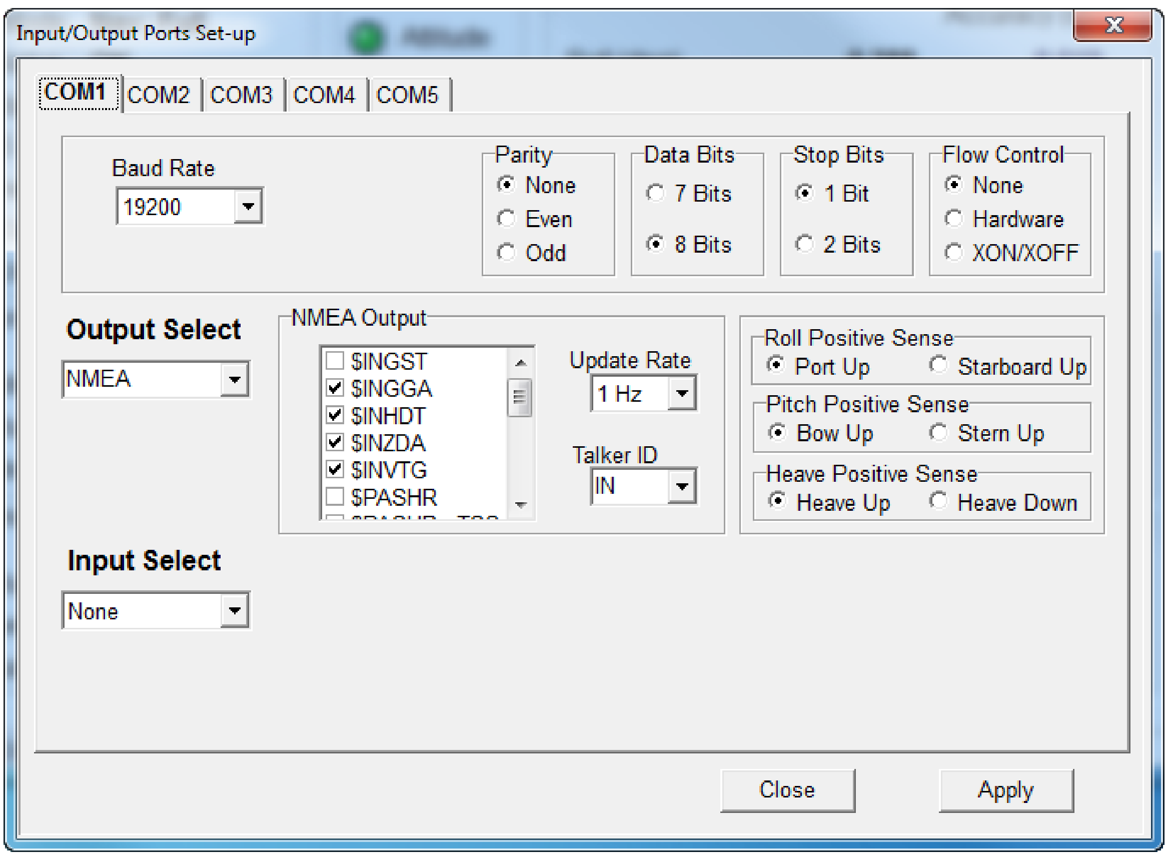

Request datagrams from EM
Echosounder
EM710_241
Datagram
Position (P)
Options
All
IP:Port
Subscribe
Unsubscribe
KONGSBERG
Please restart SIS for changes to take effect
Datagram
IP:Port
Interval
Position
localhost:16108
All
Estimated positions
localhost:16108
All
Information
localhost:9004
All
Position
localhost:9004
All
Installation
localhost:9004
All
Position
localhost:9009
All
Position
localhost:4002
All
Clock
localhost:4002
All
Information
localhost:4002
All
Depth
localhost:4002
All
Runtime
localhost:4002
All
Height
localhost:4002
All
XYZ88
localhost:4002
All
Estimated positions
localhost:4002
All
Motion sensor
localhost:4002
All
Position
HDPC:5052
All
Estimated positions
HDPC:5052
All
Watercolumn
localhost:16102
All
Stave
localhost:16102
All
Sound speed profile
10.48.16.252:16103
All
Exit
Help

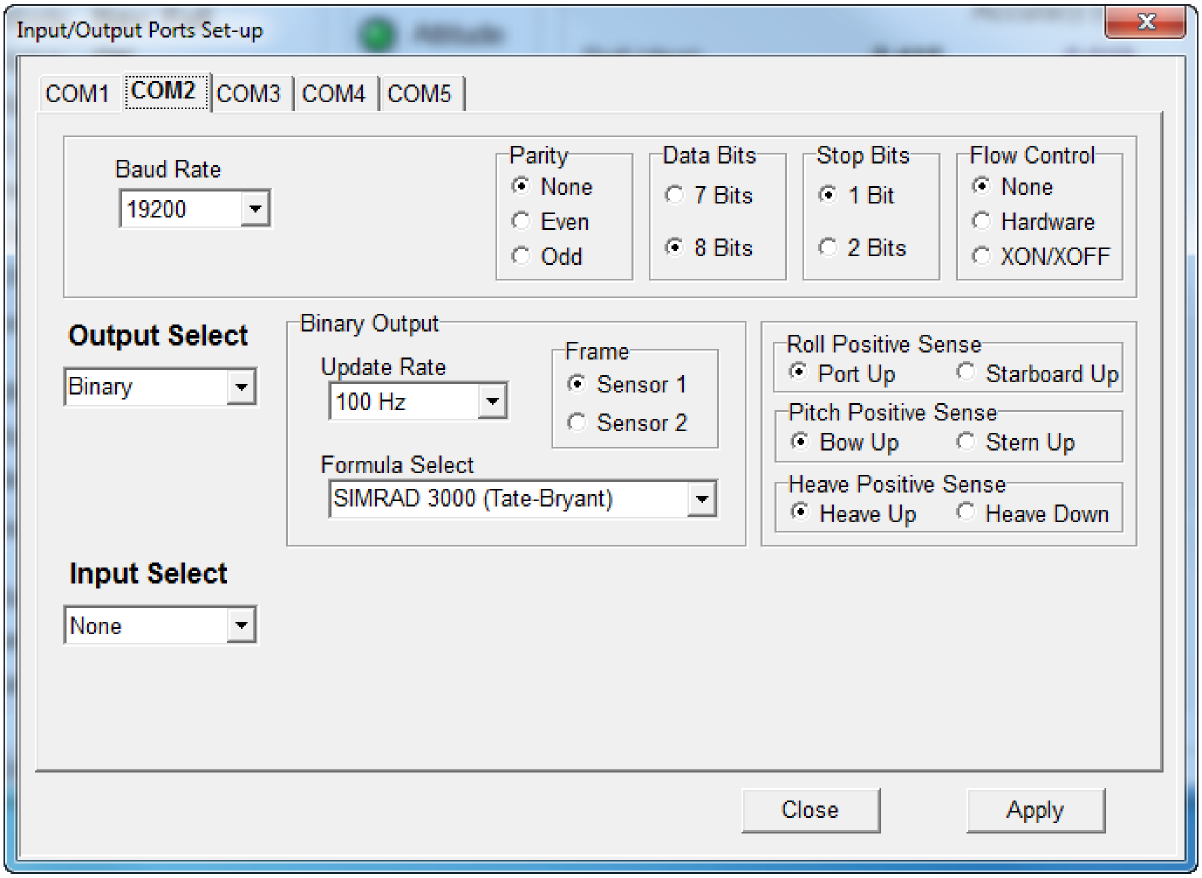
### 10.1.2 POS M/V

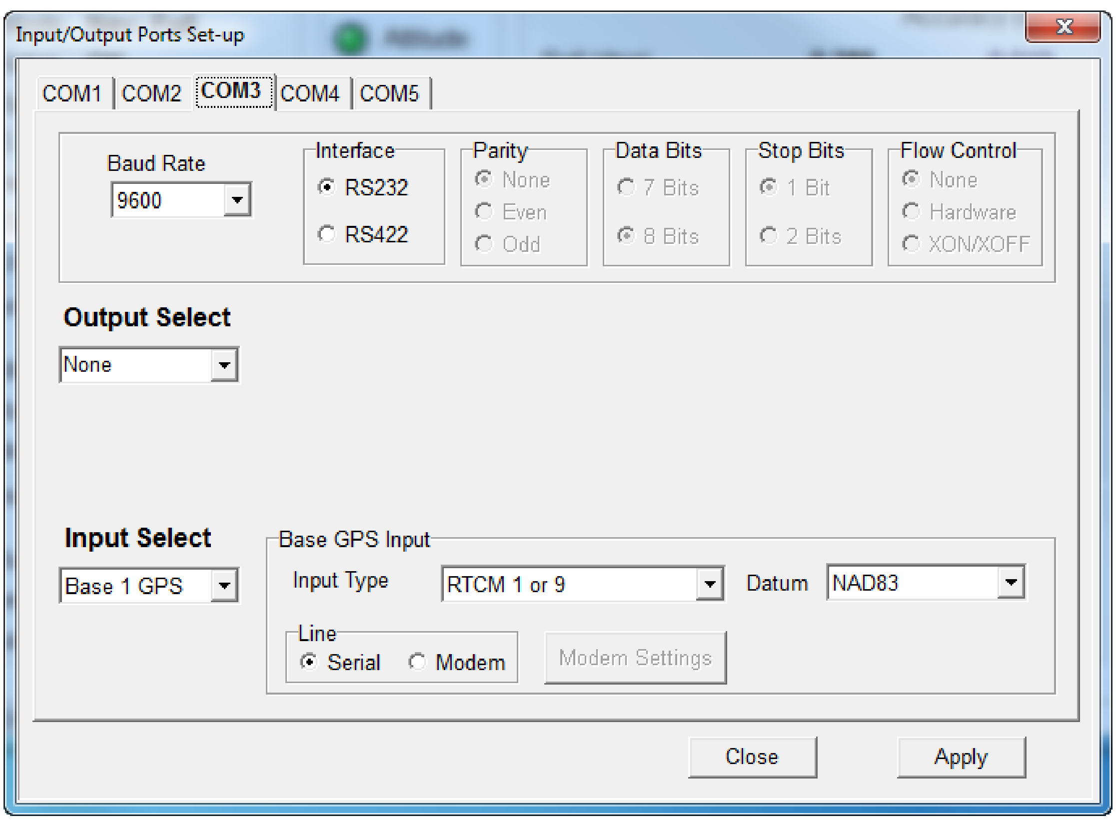

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to IMU Target
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
IMU Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Target to Sensing Centre
X (m) -0.008
Y (m) -0.031
Z (m) 0.130
Resulting Lever Arm
X (m) -0.008
Y (m) -0.031
Z (m) 0.130
Ref. to Primary GNSS Lever Arm
X (m) -9.937
Y (m) 1.389
Z (m) -22.338
Ref. to Vessel Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Centre of Rotation Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Notes:
1. Ref. = Reference
2. w.r.t. = With Respect To
3. Reference Frame and Vessel Frame are co-aligned
Compute IMU w.r.t. Ref. Misalignment
Enable Bare IMU
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !

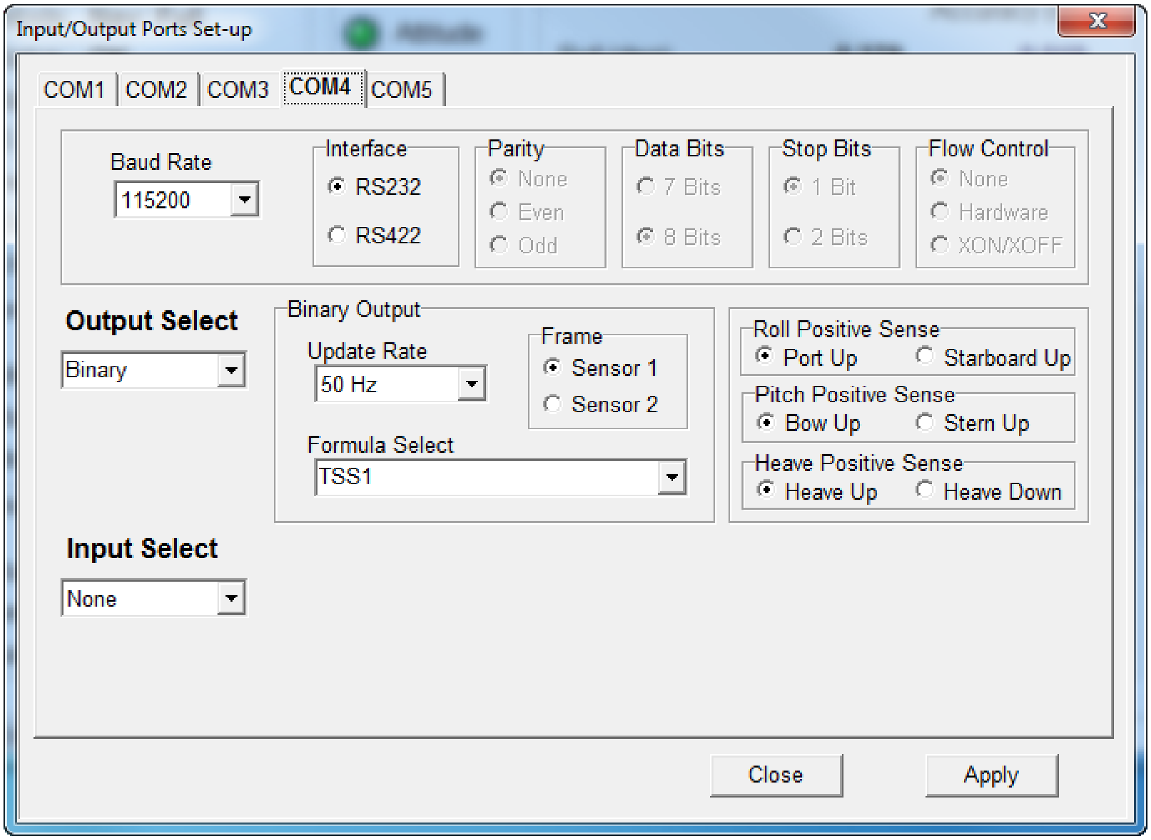

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Ref. to Aux. 1 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Aux. 2 GNSS Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Ref. to Sensor 1 Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Sensor 1 Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Ref. to Sensor 2 Lever Arm
X (m) 0.000
Y (m) 0.000
Z (m) 0.000
Sensor 2 Frame w.r.t. Ref. Frame
X (deg) 0.000
Y (deg) 0.000
Z (deg) 0.000
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !

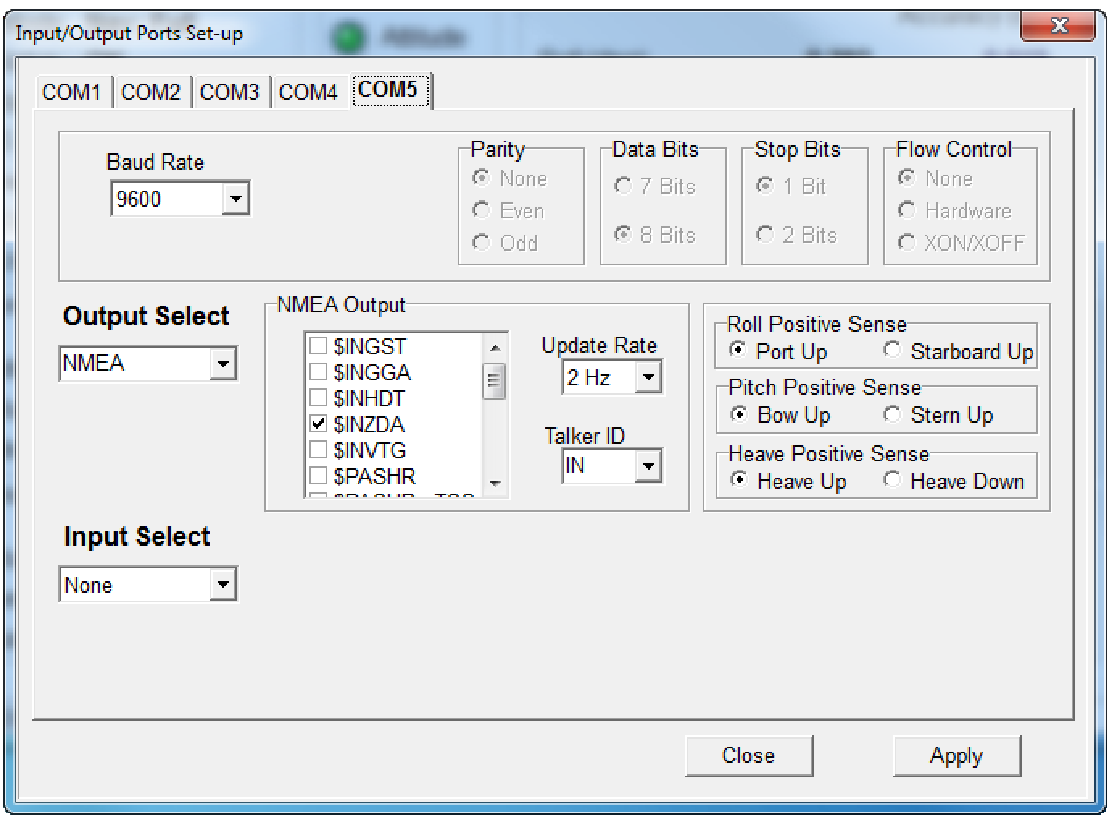

Lever Arms & Mounting Angles
Lever Arms & Mounting Angles
Sensor Mounting
Tags, AutoStart
Time Tag 1
POS Time
GPS Time
UTC Time
Time Tag 2
POS Time
GPS Time
UTC Time
User Time
AutoStart
Disabled
Enabled
Ok
Close
Apply
View
In Navigation Mode , to change parameters go to Standby Mode !

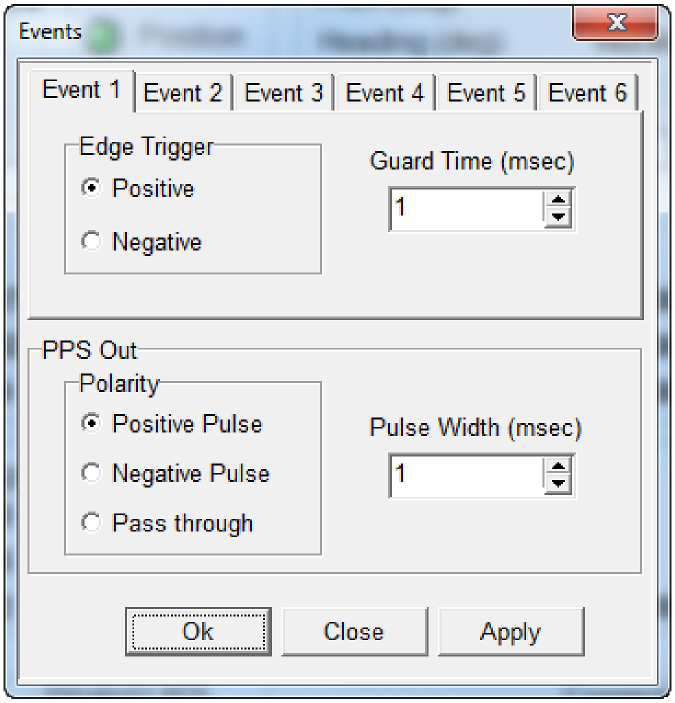

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
19200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$INGST
$INGGA
$INHDT
$INZDA
$INVTG
$PASHR
Update Rate
1 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply


Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
19200
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
Binary
Binary Output
Update Rate
100 Hz
Frame
Sensor 1
Sensor 2
Formula Select
SIMRAD 3000 (Tate-Bryant)
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

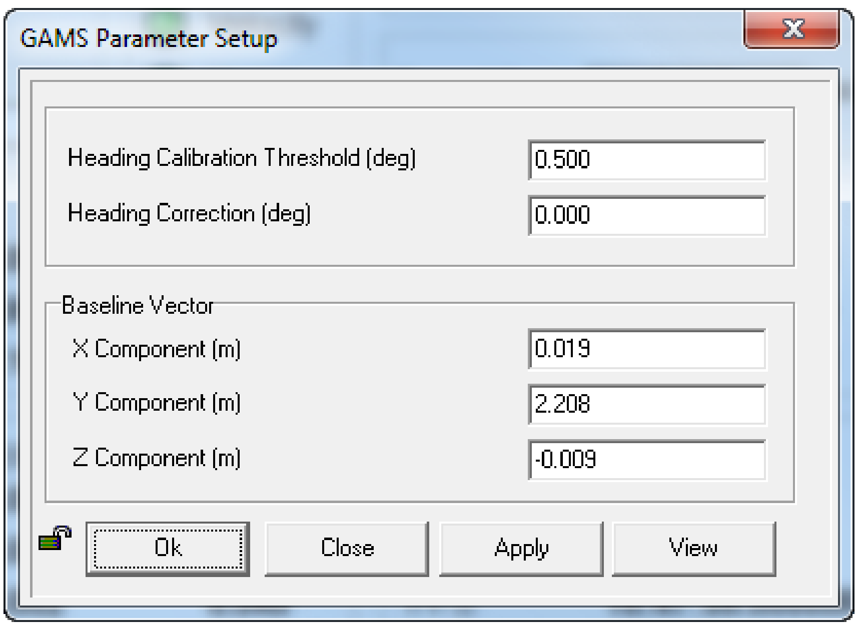

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
None
Input Select
Base 1 GPS
Base GPS Input
Input Type
RTCM 1 or 9
Datum
NAD83
Line
Serial
Modem
Modem Settings
Close
Apply


Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
115200
Interface
RS232
RS422
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
Binary
Binary Output
Update Rate
50 Hz
Frame
Sensor 1
Sensor 2
Formula Select
TSS1
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply

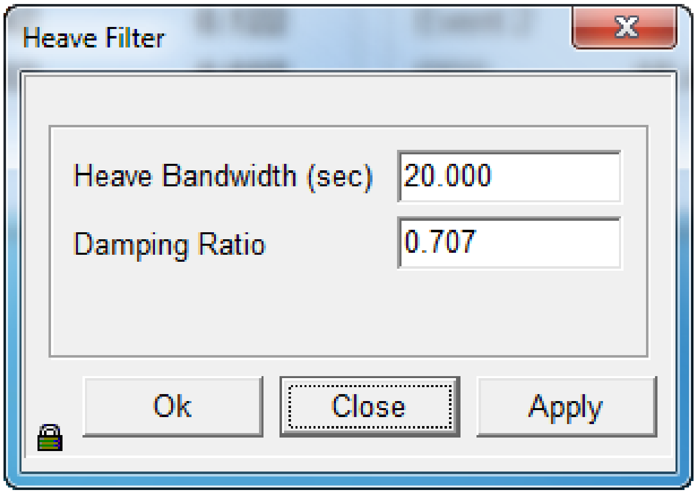

Input/Output Ports Set-up
COM1
COM2
COM3
COM4
COM5
Baud Rate
9600
Parity
None
Even
Odd
Data Bits
7 Bits
8 Bits
Stop Bits
1 Bit
2 Bits
Flow Control
None
Hardware
XON/XOFF
Output Select
NMEA
NMEA Output
$INGST
$INGGA
$INHDT
$INZDA
$INVTG
$PASHR
Update Rate
2 Hz
Talker ID
IN
Roll Positive Sense
Port Up
Starboard Up
Pitch Positive Sense
Bow Up
Stern Up
Heave Positive Sense
Heave Up
Heave Down
Input Select
None
Close
Apply



Events
Event 1
Event 2
Event 3
Event 4
Event 5
Event 6
Edge Trigger
Positive
Negative
Guard Time (msec)
1
PPS Out
Polarity
Positive Pulse
Negative Pulse
Pass through
Pulse Width (msec)
1
Ok
Close
Apply

GAMS Parameter Setup
Heading Calibration Threshold (deg)
0.500
Heading Correction (deg)
0.000
Baseline Vector
X Component (m)
0.019
Y Component (m)
2.208
Z Component (m)
-0.009
Ok
Close
Apply
View


Heave Filter
Heave Bandwidth (sec)
20.000
Damping Ratio
0.707
Ok
Close
Apply

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship THOMAS JEFFERSON S-222 | TIME ZONE +4 | DAY OF WEEK ~~TUESDAY~~ WED | DATE (dd mmm yyyy) 12 OCT 2016 |
|---|---|---|---|

KS

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | | | | | | | | | | | | | | |
| 01 | | | | | | | | | | | | | | |
| 02 | | | | | | | | | | | | | | |
| 03 | | | | | | | | | | | | | | |
| 04 | | | | | | | | | | | | | | |
| 05 | | | | | | | | | | | | | | |
| 06 | | | | | | | | | | | | | | |
| 07 | | | | | | | | | | | | | | |
| 08 | 36°57.2'N | 076°17.9'W | CLR | NSW | 10+ | 010 | 5 | 1028 | — | — | — | — | 13.8 | 13 |
| 09 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | 36°58.8'N | 076°20.7'W | FEW | ~~CA~~ -BR | 10 | 066 | 9 | 1021.6 | — | — | — | 20.3 | 19.8 | 16.7 |
| 17 | 36°58.9'N | 76°20.7'W | FEW | -BR | 10+ | 060 | 12 | 1020.1 | — | — | — | 20.2 | 20.2 | 19.6 |
| 18 | 36°58.2'N | 076°21.2'W | FEW | -BR | 10+ | 072 | 11 | 1020.4 | — | — | — | 19.1 | 19.2 | 16.9 |
| 19 | 37°00.2'N | 076°16.5'W | FEW | BR | 10 | 067 | 12 | 1020.4 | — | — | — | 20.5 | 19.1 | 16.3 |
| 20 | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | THURS | 13 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 37° 27.86'N | 076° 42.6'W | FAIR | NSW | 10 | 108 | 8 | 1019.0 | NA | NA | NA | 20.3 | 18 | 17 |
| 01 | 37° 32.5'N | 076° 06.1'N | FAIR | NSW | 10+ | 090 | 2 | 1019.9 | N/A | N/A | N/A | 19.9 | 17.9 | 17.5 |
| 02 | 37° 34.3'N | 076° 08.0'W | FAIR | NSW | 10+ | 093 | 4 | 1019.2 | N/A | N/A | NA | 19.8 | 18.2 | 17.0 |
| 03 | 37° 35.15'N | 076° 08.6'W | FAIR | NSW | 20+ | 115 | 3 | 1018.7 | N/A | N/A | N/A | 19.2 | 18.1 | 17 |
| 04 | 37° 34.2'N | 076° 07.1'W | FAIR | NSW | 10+ | 012 | 4 | 1018.6 | — | — | — | 19.2 | 18.0 | 17.1 |
| 05 | 37° 32.2'N | 076° 03.8'W | CLR | AR | 10 | 015 | 2 | 1018.5 | — | — | — | 19.5 | 17.8 | 17.1 |
| 06 | 37° 33.0'N | 076° 13.6'W | CLR | AR | 10 | 345 | 2 | 1018.6 | — | — | — | 19.4 | 17.8 | 17.2 |
| 07 | 37° 34.3'N | 076° 05.2'W | FEW | AR | 10 | 115 | 2 | 1018.3 | — | — | — | 19.1 | 17.4 | 17.1 |
| 08 | 37° 34.1N | 076° 07.7W | CLR | NSW | 10 | 250 | 4 | 1018.7 | — | — | — | 19.6 | 18.5 | 17.5 |
| 09 | — | — | — | NOT | OBSERVED | | | | — | — | — | — | — | — |
| 10 | 37° 35.7N | 076° 05.8'W | CLR | Patchy Fog | 10 | 224 | 5 | 1019.1 | — | — | — | 19.8 | 17.1 | 17.1 |
| 11 | 37° 37.6N | 076° 10.5'N | PC | NSW | 10 | 233 | 9 | 1018.5 | — | — | — | 19.8 | 17.9 | 16.9 |
| 12 | 37° 35.7'N | 076° 08.7'W | FEW | NSW | 10+ | 268 | 6 | 1018.3 | — | — | — | 20.2 | 20.5 | 19.5 |
| 13 | 37° 35.3'N | 076° 07.6'W | | NOT | | OBSERVED | | | — | — | — | — | — | — |
| 14 | 37° 32.4'N | 076° 05.9'W | PC | NSW | 10+ | 163 | 3 | 1017.1 | - | - | - | 20.6 | 22.0 | 20.5 |
| 15 | — | — | — | NOT | | OBSERVED | | | — | — | — | — | — | — |
| 16 | 37° 37.0'N | 076° 04.5'W | PC | -BR | 10 | 330 | 5 | 1016.6 | — | — | — | 21.1 | 17.3 | 15.6 |
| 17 | 37° 33.7'N | 076° 06.1'W | PC | NSW | 10 | 176 | 2.6 | 1016.5 | - | - | - | 20.7 | 20.5 | 17.5 |
| 18 | 37° 38.5'N | 076° 09.9'W | PC | NSW | 10 | 045 | 6.6 | 1017.1 | <1 | - | - | 21.1 | 20.3 | 17.9 |
| 19 | 37° 37'N | 076° 08'W | PC | NSW | 10 | 011 | 7.5 | 1018.0 | <1 | - | - | 20.9 | 19.8 | 18.0 |
| 20 | 37° 34N | 076° 06.3W | CLR | NSW | 10 | 016 | 18 | 1018.1 | <1 | — | — | 20.2 | 20.4 | 17.3 |
| 21 | 37° 37.4 | 076° 09'W | CLR | NSW | 10 | 017 | 15 | 1019.1 | <1 | — | — | 20.3 | 20.3 | 16.4 |
| 22 | 37° 35.5'N | 076° 06.5'W | CLR | NSW | 10 | 017 | 17 | 1019.7 | <1 | — | — | 19.8 | 19.8 | 16.7 |
| 23 | 37° 34.9'N | 076° 06.6'W | CLR | NSW | 10 | 015 | 15 | 1020.4 | 1-2 | — | — | 19.8 | 19.5 | 16.8 |
| | | | | | | | | | | | | | | |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | FRIDAY | 14 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB | |
| 00 | 37°35.0'N | 076°06.0'W | OVC | +BR | 10 | 355 | 23.3 | 1020 | 2-3 | 340 | 2-3 | 19.8 | 19.1 | 15.6 | |
| 01 | 37°35.7'N | 076°07.3'W | OVC | +BR | 10+ | [illegible] | 23 | 1021 | 2-3 | 340 | 1-2 | 19.9 | 19.0 | 16.5 | |
| 02 | 37°28.8'N | 076°06.2'W | OVC | +BR | 10+ | 354 | 27 | 1022 | 0-1 | 340 | 0-1 | 19.8 | 17.0 | 16.0 | |
| 03 | 37°23.7'N | 076°06.0'W | OVC | +BR | 10+ | 352 | 22 | 1022 | 0-1 | 340 | 0-1 | 20.2 | 17.0 | 16.0 | |
| 04 | 37°13.6'N | 076°07.9'W | MC | +BR | 10 | 359 | 22 | 1022 | 1 | 330 | 1 | 20.2 | 17.1 | 14.3 | |
| 05 | 37°06.4'N | 076°01.3'W | MC | BR | 10 | 012 | 20 | 1022.6 | 1 | 330 | 2 | 19.6 | 17 | 13.3 | |
| 06 | 37°00.0'N | 076°02.1'W | MC | BR | 10 | 013 | 18 | 1023.1 | 1-2 | ĊFSD | 2 | 19.3 | 15.9 | 12.4 | |
| 07 | 36°57.9'N | 076°04.0'W | PC | BR | 10 | 030 | 18 | 1024.8 | 2-3 | 330 | 2-3 | 19.7 | 15.5 | 13.7 | |
| 08 | 37°00.3'N | 076°13.7'W | PC | BR | 10 | 038° | 19 | 1023.9 | 2 | 335 | 2 | 20.2 | 13.7 | 12.7 | |
| 09 | | | | | NOT | OBSERVED | | | | | | | | | |
| 10 | | | | | NOT | OBSERVED | | | | | | | | | |
| 11 | | | | | NOT | OBSERVED | | | | | | | | | |
| 12 | | | | | NOT | OBSERVED | | | | | | | | | |
| 13 | | | | | NOT | OBSERVED | | | | | | | | | |
| 14 | 36°59.0'N | 076 19.9'W | SCT | ~~BCF~~ NSW | 10 | 022 | 12 | 1025.7 | 1 | 191 | 1 | 20.0 | 17.0 | 12.5 | NB |
| 15 | 13°05.0'N | 076 20.1'W | SCT | NSW | 10 | 039 | 38 | 1025.7 | 1 | 055 | 1 | 20.0 | 17.0 | 12.1 | |
| 16 | 36°58.9'N | 076°20.1'W | MC | BR | 10 | 040 | 13 | 1025.7 | 1 | — | — | 20.0 | 16.0 | 11.6 | |
| 17 | | | | | | | | | | | | | | | |
| 18 | 36°57.6'N | 076°01.9'W | MC | -BR | 10 | 025 | 8 | 1025.3 | 1 | 045 | 1 | 19.8 | 16.0 | 11.3 | |
| 19 | 36°56.1'N | 075°53.0'W | MC | -BR | 10 | 053 | 7 | 1025.3 | 1-2 | 045 | 2 | 20.0 | 15.7 | 11.6 | |
| 20 | 36°58.3'N | 075°17.1 | MC | -BR | 10 | 030 | 9 | 1025.3 | 1-2 | 045 | 2 | 19.9 | 15.6 | 12 | |
| 21 | 37°00.9'N | 075°27.2'W | ~~CLR~~ MC | BR | 10 | 046 | 11 | 1025.9 | 1-2 | 045 | 2 | 19.4 | 15.5 | 11.6 | KS |
| 22 | 37°03.3N | 075°15.3'W | ~~CLR~~ MC | -BR | 10 | 054 | 7 | 1026.4 | ~~1-2~~ 2-3 | 040 | ~~3~~ | 19.3 | 15.3 | 11.9 | KS |
| 23 | 37°08.7 | 075°09.7 | MC | BR | 10 | 050 | 11 | 1026.4 | ~~4-5~~ 2-3 | 040 | 4-5 | 19.1 | 15.2 | 12.3 | KS |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | SATURDAY | 15 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 37° 14.6'N | 075° 02.0'W | FAIR | NSW | 10 | 074 | 12.7 | 1026.5 | 2-3 | 040 | 3-4 | 19 | 15.2 | 11.8 |
| 01 | 37° 22'N | 074° 53.8'W | FAIR | NSW | 10 | 050 | 10 | 1026.7 | 2-3 | 045 | 3-4 | 18.4 | 15.2 | 11.8 |
| 02 | 37° 25'N | 074° 49'W | FAIR | BR | 10 | 060 | 13 | 1026.7 | 2-3 | 050 | 3-4 | 18.5 | 15.3 | 11.7 |
| 03 | 37° 31'N | 074° 41.0'W | FAIR | BR | 10 | 076 | 11 | 1026 | 1-2 | 010 | 3-4 | 17.8 | 15.6 | 11.7 |
| 04 | 37° 26.8'N | 074° 35.2'W | FAIR | BR | 10 | 080 | 11 | 1025.8 | 1-2 | 020 | 3-4 | 18.2 | 15.8 | 11.6 |
| 05 | 37° 42.1'N | 074° 28.5'W | FAIR | BR | 10 | 015 | 8 | 1025.8 | 1-2 | 030 | 1-2 | 18.3 | 15.9 | 11.8 |
| 06 | 37° 48.3'N | 074° 21.3'W | FAIR | BR | 10 | 015 | 3 | 1025.9 | 1-2 | 030 | 1-2 | 17.8 | 16.0 | 12.0 |
| 07 | 37° 53.6'N | 074° 15.6'W | FAIR | BR | 10 | 350 | 7 | 1026.7 | 1-2 | 060 | 1-2 | 18.9 | 16.3 | 12.7 |
| 08 | | | | | | | | | | | | | | |
| 09 | 37° 53.1'N | 074° 15.5'W | FAIR | -BR | 10 | 020 | 8 | 1027.9 | 1-2 | 070 | 1-2 | 18.7 | 16.5 | 13.2 |
| 10 | 37° 52.9'N | 074° 15.6'W | FAIR | BR | 10 | 033 | 13 | 1028.5 | 1-2 | 070 | 1-2 | 18.6 | 16.4 | 13.2 |
| 11 | 37° 52.9'N | 074° 14.18'W | FAIR | BR | 10 | 030 | 13 | 1028.1 | 1-2 | 075 | 1-2 | 18.6 | 16.4 | 13.4 |
| 12 | 37° 53.7'N | 074° 15.0'W | CLR | BR | 10 | 033 | 13 | 1028 | 1-2 | 080 | 1-2 | 18.8 | 18.0 | 13.8 |
| 13 | 37° 52.4'N | 074° 14.3'W | HZ | BR | 10 | 038 | 15 | 1027.1 | 1-2 | 070 | 2-3 | 18.9 | 17.1 | 14.3 |
| 14 | 37° 51.7'N | 074° 09.0'W | FEW | -BR | 10+ | 037 | 13 | 1026.6 | 1-2 | 070 | 1-2 | 20.3 | 17.8 | 14.9 |
| 15 | 37° 48.7'N | 074° 06.N'W | FEW | -BR | 10+ | 065 | 10 | 1026.4 | 1-2 | 060 | 1-2 | 20.9 | 19.8 | 14.9 |
| 16 | 37° 52.3'N | 074° 03.1'W | FEW | NSW | 10+ | 105 | 13 | 1025.8 | 1-2 | 050 | 1-2 | 20.2 | 18.6 | 14.0 |
| 17 | | | | | | | | | | | | | | |
| 18 | 38° 11.0'N | 073° 51.5'W | FEW | NSW | 10+ | 115 | 12 | 1025.5 | <1 | 040 | 1-2 | 20.6 | 18.0 | 12.9 |
| 19 | 38° 19.9'N | 073° 43.1'W | FEW | -BR | 10+ | 095 | 12 | 1025.8 | 1-2 | 045 | 2-3 | 20.4 | 17.9 | 13.6 |
| 20 | 38° 27.1'N | 073° 31.6'W | FEW | -BR | 10+ | 103 | 11 | 1025.8 | 1-2 | 045 | 2-3 | 20.5 | 17.5 | 13.0 |
| 21 | 38° ~~31.29~~ 35.2'N | 073° 24.8'W | FEW | -BR | 10+ | 122 | 9 | 1025.8 | 1-2 | 045 | 2-3 | 20.0 | 17.0 | 12.5 |
| 22 | 38° 43.0'N | 073° 15.3'W | FEW | -BR | 10+ | 135 | 8 | 1025.8 | 1-2 | 045 | 2-3 | 20.4 | 16.8 | 12.4 |
| 23 | 38° 51.7'N | 073° 04.4'W | FEW | -BR | 10+ | 136 | 9 | 1025.4 | 1-2 | 045 | 2-3 | 20.6 | 16.8 | 12.1 |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | ~~SATURDAY~~ SUNDAY | 16 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 38°58'N | 072°56'W | FAIR | NSW | 10+ | 188 | 8.4 | 1025.5 | 1-2 | 075 | 2-3 | 20.3 | 16.7 | 12.5 |
| 01 | | | | NOT OBSERVED | | | | | | | | | | |
| 02 | | | | | NOT OBSERVED | | | | | | | | | |
| 03 | 39°09.0'N | 072°43'W | FAIR | NSW | 10 | 190 | 2 | 1024 | — | 065 | 1-2 | 20.9 | 16.4 | 12.3 |
| 04 | 39°10.4'N | 072°44.4'W | MC/BKN | NSW | 10 | 235 | 3 | 1024.4 | <1 | 075 | 1-2 | 20.7 | 16.5 | 12.7 |
| 05 | 39°09.2'N | 072°41.9'W | MC | -BR | 10 | 251 | 9 | 1024.1 | — | 090 | 2 | 20.7 | 16.5 | 12.1 |
| 06 | 39°09.3'N | 072°40.0'W | PC/SCT | NSW | 10+ | 205 | 4 | 1023.8 | <1 | 080 | 2-3 | 20.7 | 16.5 | 12.2 |
| 07 | 39°07.9'N | 072°41.2'W | PC/SCT | NSW | 10+ | 205 | 6 | 1023.5 | <1 | 080 | 2-3 | 21.2 | 16.8 | 12.7 |
| 08 | 39°15.7'N | 072°26.2'W | PC/SCT | NSW | 10+ | 225 | 4 | 1023.2 | <1 | 080 | 2-3 | 21.1 | 17.2 | 12.8 |
| 09 | 39°27.0'N | 072°31.5'W | PC | NSW | 10+ | 205 | 8 | 1023.0 | <1 | 085 | 2-3 | 21.1 | 17.2 | ~~4.~~ 12.7 KS |
| 10 | 39°36.9'N | 072°27.5'W | PC | NSW | 10+ | 217 | 8 | 1022.5 | <1 | 085 | 1-2 | 21.0 | 17.3 | 13.5 |
| 11 | 39°37.9'N | 072°28.5'W | SCT | -BR | 10+ | 239 | 11 | 1021.3 | 1 | 110 | 1-2 | 20.5 | 17.8 | 13.8 |
| 12 | 39°37.3'N | 072°29.0'W | SCT | -BR | 10+ | 231 | 11.8 | 1021.0 | 1 | 110 | 1-2 | 20.5 | 18.5 | 14.3 |
| 13 | 39°37.2'N | 072°28.2'W | -SCT | BR | 10+ | 241 | 11.9 | 1020.8 | 1-2 | 120 | 2-3 | 20.5 | 17.9 | 13.8 |
| 14 | 39°37.3'N | 072°28.9'W | SCT | BR | 10+ | 250 | 12.9 | 1020.0 | 1-2 | 100 | 2-3 | 20.5 | 17.8 | 14.3 |
| 15 | 39°33.3'N | 072°32.9'W | SCT | BR | 10+ | 225 | 17 | 1017.8 | 1-2 | 120 | 2-3 | 20.4 | 18.0 | 14.4 |
| 16 | 39°20.7'N | 072°22.9'W | SCT | BR | 10+ | 245 | 14 | 1017.2 | 1-2 | 110 | 2-3 | 21.0 | 18.1 | 14.5 |
| 17 | 39°18.7'N | 072°20.8'W | FEW | BR | 10+ | ~~235~~ 225 | 15 | 1016.6 | 1-2 | 100 | 2-3 | 21.6 | 18.4 | 15.4 |
| 18 | ~~39°17.2'N~~ | ~~072°22.8'W~~ | ~~FEW~~ | ~~BR~~ | ~~10+~~ | ~~250~~ | ~~17~~ | ~~1017.1~~ | ~~1-2~~ | ~~100~~ | ~~2-3~~ | ~~21.0~~ | ~~18.6~~ | ~~15.8~~ |
| 19 | | | | | | | | | | | | | | |
| 20 | 39°17.2'N | 072°22.8'W | FEW | BR | 10+ | 250 | 17 | 1017.1 | 1-2 | 100 | 2-3 | 21.6 | 18.6 | 15.8 |
| 21 | 39°19.5'N | 072°19.9'W | FEW | BR | 10+ | 249 | 19 | 1016.7 | 1-2 | 100 | 2-3 | 21.6 | 19.2 | 16.2 |
| 22 | 39°18.6'N | 072°21.4'W | FEN | BR | 10+ | 240 | 17 | 1016.6 | 1-2 | 110 | 2-3 | 21.6 | 19.3 | 16.4 |
| 23 | 39°17.8'N | 072°20.07'W | FEW | BR | 10+ | 246 | 20 | 1016.7 | 2 | 110 | 3 | 21.7 | 19.8 | 16.5 |
| | | | | | | | | | | | | | | |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | MONDAY | 17 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 39° 18.3'N | 072° 21.1'W | CLR | FAIR | 10 | 245 | 205 | 1015.6 | 1-2 | 240 | 2-3 | 21.5 | 19.8 | 16.8 |
| 01 | 039° 18.6'N | 072 21.5'W | CLR | BR | 10 | ~~21~~ 253 | ~~253~~ 21 | 1015.9 | 1-2 | 240 | 2-3 | 21.6 | 20.0 | 17.0 |
| 02 | 39° 19 'N | 072° 19.9'W | CLR | BR | 10 | 265 | 20 | 1015.5 | 1-2 | 250 | 2-3 | 21.5 | 19.8 | 17.2 |
| 03 | | | | | | | | | | | | | | |
| 04 | | | | | | | | | | | | | | |
| 05 | 39° 15.9'N | 072° 19.7'W | OVC | BR | 10 | 265 | 15 | 1014.4 | 1-2 | 240 | 2-3 | 20.1 | 20.2 | 17.7 |
| 06 | 39° 17.1'N | 072° 11.7'W | [illegible] | BR | 10+ | 260 | 15 | 1014.7 | 1-2 | 240 | 2-3 | 22.0 | 20.1 | 18.1 |
| 07 | 39° 17.6'N | 072° 09.3'W | SCT | BR | 10 | | | | 1-2 | 260 | 3 | 21.8 | 20.5 | 18.1 |
| 08 | 39° 16.6'N | 072° 12.2'W | PC | BR | 10+ | 248 | 15 | 1014.7 | 1-2 | 260 | 3 | 22.1 | 20.3 | 18.2 |
| 09 | 39° 17.7'N | 072° 12.8'W | PC | BR | 10+ | 244 | 17 | 1014.9 | 1-2 | 260 | 3 | 21.8 | 20.5 | 18.4 |
| 10 | 39° 17.7'N | 072° 11.3'W | PC | BR | 10+ | 243 | 20 | 1013.7 | 1-2 | 250 | 3 | 21.9 | 21.1 | 18.9 |
| 11 | 39° 18.0'N | 072° 11.57'W | PC | BR | 10+ | 243 | 19 | 1013.4 | 3 | 255 | 3 | 21.9 | 21.5 | 19.1 |
| 12 | 39° 18.7'N | 072° 12.2'W | CLR | BR | 10+ | 247 | 19 | 1013.8 | 2-3 | 275 | 2-3 | 21.7 | 20.8 | 18.9 |
| 13 | ← NOT OBS; DRILLS → | | | | | | | | | | | | | |
| 14 | 39° 17.4'N | 072° 12.4'W | CLR | BR | 10+ | 259 | 18 | 1012.8 | 2-3 | 275 | 2-3 | 21.8 | 21.2 | 18.6 |
| 15 | | | | | | | | | | | | | | |
| 16 | 39° 18.1'N | 072° 11.7'W | CLR | BR | 10 | 250 | 17 | 1012.0 | 2-3 | 210 | 2-3 | 22.0 | 21.2 | 18.6 |
| 17 | 39° 18.5'N | 072° 10.9'W | CLR | BR | 10+ | 242 | 14 | 1012.2 | 2-3 | 210 | 2-3 | 21.6 | 21.5 | 18.9 |
| 18 | 39° 16.9'N | 072° 13.7W | CLR | BR | 10 | 226 | 14 | 1012.0 | 2 | 210 | 2-3 | 21.9 | 21.0 | 18.9 |
| 19 | 39° 17.1'N | 072° 13.4'W | CLR | BR | 10 | 240 | 17 | 1012.1 | 1-2 | 210 | 2-3 | 22 | 21.3 | 19.2 |
| 20 | | | | | | | | | | | | | | |
| 21 | 39° 09.0'N | 072° 14.6'W | CLR | BR | 10 | 226 | 18 | 1012.6 | 1-2 | 200 | 2-3 | 22 | 21.3 | 19.7 |
| 22 | 39° 03.4'N | 072° 09.9'W | CLR | BR | 10 | 224 | 19 | 1012.8 | 1-2 | 200 | 2-3 | 21.2 | 21.4 | 19.6 |
| 23 | 38° 56.6'N | 072° 04.0'W | CLR | BR | 10 | 233 | 19 | 1012.7 | 1-2 | 200 | 2-3 | 22.9 | 22.5 | 20.0 |
| | | | | | | | | | | | | | | |



SUPERSEDES NOAA Form 77-13D (3-76)

NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | TUESDAY | 18 OCT 2Ø16 |

| TIME | POSITION | | SKY CON-DITION | PRESENT WEATHER | VISI-BILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 38° 55.15'N | Ø72° Ø3.95'W | CLR | BR | 1Ø+ | 237 | 15 | 1Ø13.5 | 1-2 | – | 2-3 | 22.1 | 22.3 | 19.1 |
| 01 | 39° Ø1.1'N | Ø71° 58.Ø W | CLR | BR | 1Ø+ | 242 | 17 | 1Ø13.6 | 1-2 | – | 2-3 | 22.1 | 22.2 | 19.8 |
| 02 | 38° 57.35'N | Ø72° Ø3.8'W | CLR | BR | 1Ø+ | 243 | 19 | 1Ø13.6 | 1-2 | – | 2-3 | 23.Ø | 22.1 | 19.6 |
| 03 | 38° 59.9'N | Ø72° Ø8.1'W | CLR | BR | 1Ø+ | 235 | 17 | 1Ø13.4 | 1-2 | – | 2-3 | 23.1 | 21.9 | 19.8 |
| 04 | 39° 10.5'N | 072° 14.5'W | CLR | +BR | 10 | 235 | 18 | 1Ø13.3 | 1-2 | 210 | 2-3 | 22.0 | 21.5 | 19.8 |
| 05 | 39° 14.7'N | 072° 20.4'W | CLR | +BR | 10 | 235 | 17 | 1013.4 | 1-2 | 210 | 2 | 21.2 | 21.1 | 19.6 |
| 06 | 39° 18.5'N | 072° 21.7'W | CLR | BR | 10 | 235 | 16 | 1013.4 | 1-2 | 220 | 2 | 21.0 | 21.1 | 19.2 |
| 07 | 39° 18.4'N | 072° 21.8'W | FEW ~~CLR~~ | -BR | 10+ | 225 | 12 | 1013.8 | 1-2 | 190 | 2-3 | 21.0 | 21.0 | 19.8 |
| 08 | 39° 19.3'N | 072° 22.ØW | FEW | -BR | 10+ | 220 | 12 | 1Ø14.1 | 1-2 | 19Ø | 2-3 | 21.4 | 21.5 | 20.Ø |
| 09 | 39° 18.5'N | Ø72° 21.1'W | FEW | -BR | 10+ | 213 | 11 | 1Ø14.6 | 1-2 | 21Ø | 2-3 | 21.5 | 21.5 | 20.1 |
| 10 | 39° 24.1'N | Ø72° 25.4'N | FEW | -BR | 10+ | 2Ø9 | 12 | 1Ø14.4 | 1-2 | 21Ø | 2 | 21.1 | 21.2 | 20.1 |
| 11 | 39° 33.85'N | 072° 32.76'W | FEW | -BR | 10+ | 211 | 12 | 1013.9 | 1-2 | 210 | 2 | 20.49 | 20.9 | 19.7 |
| 12 | 39° 37.5'N | Ø72° 37.3'W | CLR | BR | 1Ø+ | 228 | 18 | 1Ø13.5 | Ø-1 | 2ØØ | 1-2 | 2Ø.6 | 18.6 | 19.3 |
| 13 | 39° 29.4'N | Ø72° 44.7'W | CLR | BR | 1Ø+ | 215 | 19 | 1Ø12.9 | Ø-1 | 2ØØ | 1-2 | 2Ø.Ø | 2Ø.6 | 19.2 |
| 14 | 39° 22.4'N | Ø72° 5Ø.7'W | CLR | BR | 1Ø+ | 215 | 19 | 1Ø12.6 | Ø-1 | 19Ø | Ø-1 | 21.Ø | 2Ø.8 | 19.2 |
| 15 | 39° 17.5'N | Ø72° 56.1'W | CLR | BR | 1Ø+ | 2ØØ | 18 | 1Ø12.3 | 1 | 19Ø | 1-2 | 19.5 | 2Ø.8 | 19.1 |
| 16 | 39° 09.3'N | Ø73° 03.8'W | CLR | BR | 10 | 210 | 19 | 1Ø12.4 | 1 | 19Ø | 1-2 | 18.7 | 20.5 | 19.2 |
| 17 | 39° ØØ.1'N | Ø73° 12.3'W | CLR | BR | 1Ø+ | 2Ø3 | 19 | 1Ø12.2 | 1 | 19Ø | 1-2 | 18.6 | 2Ø.4 | 19.4 |
| 18 | 38° 52.3'N | 073° 19.9'W | CLR | BR | 10 | 200 | 18 | 1012.7 | 1 | 190 | 1-2 | 19.7 | 20.3 | 19.4 |
| 19 | 38° 45.4'N | 073° 27.0'W | CLR | BR | 10 | 200 | 20 | 1012.7 | 1-2 | 180 | 2 | 18.9 | 20.4 | 19.3 |
| 20 | 38° 37.7'N | Ø73° 33.9'W | CLR | BR | 10 | 200 | 2Ø | 1Ø12.7 | 1-2 | 19Ø | 1-2 | 18.9 | 2Ø.8 | 19.4 |
| 21 | 38° 26.2'N | Ø73° 44.7'W | CLR | BR | 10+ | 2Ø5 | 23 | 1Ø13.Ø | 1-2 | 19Ø | 2 | 19.2 | 21.1 | 19.6 |
| 22 | 38° 18.6'N | Ø73° 51.7'W | CLR | BR | 10 | 212 | 24 | 1Ø13.3 | 2-3 ~~1-2~~ | 19Ø | ~~2~~-3 | 19.3 | 2Ø.8 | 19.4 |
| 23 | 38° 10.6'N | Ø73° 59.Ø | CLR | BR | 10 | 215 | 25 | 1Ø13.7 | 3-4 | 2ØØ | 4-5 | 18.4 | 20.4 | 18.8 |
| | | | | | | | | | | | | | | |



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NOAA Form 57-11-13D
(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | WEDNESDAY | 19 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 38° 04'N | 074° 04'W | FAIR | BR | 10 | 222 | 23 | 1014 | 2-3 | 220 | 2-3 | 18.2 | 20.2 | 18.8 |
| 01 | 37°55.1'N | 074°14.2'W | FAIR | +BR | 10+ | 210 | 25 | 1014.4 | 2-3 | 220 | 2-3 | 18.9 | 20.2 | 19.2 |
| 02 | 37°52.5'N | 074°16.7'W | FAIR | BR | 10+ | 216 | 20 | 1014.7 | 2-3 | 220 | 2-3 | 18.9 | 20.0 | 19.2 |
| 03 | 37°53.3'N | 074°15.5'W | FAIR | BR | 10 | 222 | 19 | 1014.2 | 2-3 | 220 | 2-3 | 19.0 | 20.3 | 19.0 |
| 04 | 37°53.2'N | 074°15.5'W | CLR | BR | 10 | 228 | 21 | 1013.8 | 2-3 | 220 | 2-3 | 18.9 | 20.3 | 18.8 |
| 05 | 37°53.6'N | 074°15.3'W | FAIR | BR | 10 | 220 | 16 | 1014.4 | 2-3 | 220 | 2-3 | 18.9 | 20 | 18.9 |
| 06 | 37°53.4'N | 074°15.4'W | CLR | BR | 10 | 227 | 14 | 1014.4 | 2 | 220 | 2-3 | 18.9 | 20 | 18.9 |
| 07 | 37°53.5'N | 074°15.2'W | FEW | BR | 10 | 225 | 16 | 1014.9 | 2 | 220 | 2-3 | 18.8 | 19.8 | 18.9 |
| 08 | 38°00.35N | 074°14.17W | FEW | BR | 10 | 215 | 18 | 1015.2 | 2 | 220 | 2-3 | 18.8 | 20.0 | 19.0 |
| 09 | 37°53.68N | 074 15.63W | FEW ~~HZ~~ | HZ | 10 | 225 | 15.6 | (inside) 1017.5 | 2-3 | 196 | 3 | METENG 16.1 | 20.0 | 19.5 |
| 10 | 37°53.6'N | 074° 15.3'W | FEW | HZ | 10 | 223 | 15 | 1015.8 | 2-3 | 200 | 3 | 18.9 | 20.6 | 19.1 |
| 11 | 37°53.716' | 074°15.88'W | FEW | HZ | 10 | 225 | 16 | SCS 1016.25 | 2-3 | 200 | 3 | 18.9 | 19.96 | 19.0 |
| 12 | 37°53.6'N | 074°15.5'W | CLR | HZ | 10 | 224 | 14 | 1015.5 | 1-2 | 190 | 2-3 | 19.1 | 20.6 | 19.4 |
| 13 | 37°53.7'N | 074°15.2'W | CLR | BR | 10+ | 224 | 13 | 1015.3 | 1-2 | 190 | 1-2 | 19.1 | 20.1 | 19.1 |
| 14 | 37°53.7'N | 074°15.1'W | CLR | BR | 10+ | 227 | 11.7 | 1015.1 | 1-2 | 190 | 2 | 19.0 | 20.9 | 19.1 |
| 15 | 3 | | | | | | | | | | | | | |
| 16 | 37°52.9'N | 074°14.3'W | FEW | BR | 10 | 230 | 13 | 1014.9 | 1-2 | 190 | 2-3 | 19.3 | 20.4 | 19.3 |
| ~~17~~ | | | | | | | | | | | | | | |
| 18 | 37°41.8'N | 074°29.3'W | FEW | BR | 10 | 205 | 10 | 1015.6 | 1-2 | 210 | 1-2 | 19.2 | 20.1 | 19.3 |
| 19 | 37°39.0'N | 074°33.0'W | FEW | -BR | 10 | 245 | 5 | 1016.0 | 1-2 | 200 | 1-2 | 19.2 | 19.9 | 19.4 |
| 20 | 37°34.4'N | 074°38.6'W | FEW | -BR | 10 | 239 | 4 | 1016.6 | 1-2 | 200 | 1-2 | 19.1 | 20.0 | 19.7 |
| 21 | 37°29.2'N | 074°44.5'W | FEW | -BR | 10 | 202 | 7 | 1016.6 | 1-2 | 200 | 1-2 | 19.8 | 20.2 | 19.9 |
| 22 | 37°22.1'N | 074°52.4'W | FEW | HZ | 10 | 193 | 7 | 1017.1 | 1-2 | 200 | 1-2 | 19.8 | 20.2 | 19.9 |
| 23 | 37°15.1'N | 075°00.0'W | FEW | HZ | 10 | 193 | 9 | 1017.0 | 1-2 | 200 | 1-2 | 19.8 | 20.6 | 20.2 |



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(10-12)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

# DECK LOG – WEATHER OBSERVATION SHEET

| NOAA Ship | TIME ZONE | DAY OF WEEK | DATE (dd mmm yyyy) |
|---|---|---|---|
| THOMAS JEFFERSON S-222 | +4 | THURSDAY | 20 OCT 2016 |

| TIME | POSITION | | SKY CONDITION | PRESENT WEATHER | VISIBILITY (nm) | WIND | | SEA LEVEL Press. (mb) | SEA WAVE Height (ft) | SWELL WAVES | | TEMPERATURE (°C) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LATITUDE | LONGITUDE | | | | Dir. (true) | Speed (kts) | | | Dir. (true) | Height (ft) | SEA WATER | DRY BULB | WET BULB |
| 00 | 37°07.0'N | 075°08.0'W | CLR | NSW | 10 | 203 | 11 | 1017.0 | 1-2 | 190 | 1-2 | 20.0 | 20.9 | 20.4 |
| 01 | 37°03.0'N | 075°12.9'W | CLR | NSW | 10 | 204 | 9.7 | 1017.0 | 1-2 | 190 | 1-2 | 19.9 | 21.1 | 20.5 |
| 02 | 37°02.0'N | 075°18.5'W | CLR | NSW | 10 | 198 | 10.2 | 1016.7 | 1-2 | 180 | 0-1 | 20.4 | 21.3 | 20.5 |
| 03 | 37°03.1'N | 075°13.2'W | CLR | NSW | 10+ | 195 | 10 | 1016.3 | 1-2 | 180 | 1-2 | 20.1 | 20.9 | 20.3 |
| 04 | 37°03.5'N | 075°14.4'W | PC | NSW | 10 | 192 | 12 | 1016.0 | 1-2 | 180 | 1-2 | 20.2 | 20.9 | 20.3 |
| 05 | 37°02.9'N | 075°18.6'W | FAIR | NSW | 10 | 190 | 10 | 1016.2 | 1-2 | 180 | 1-2 | 20.5 | 21.1 | 20.4 |
| 06 | 37°03.5'N | 075°14.3'W | FAIR | -BR | ~~10+~~ 10 | 180 | 11 | 1016.6 | 1-2 | 200 | 1-2 | 20.2 | 20.9 | 20.2 |
| 07 | 37°03.6'N | 075°13.8'W | FEW | -BR | 10 | 180 | 10 | 1016.6 | <1 | 180 | 1-2 | 20.2 | 20.8 | 20.1 |
| AK 08 | 37°03.09'N | 075°16.9'W | CLR F | BR | 10 | 179 | 12 | 1016.9 | <1 | 180 | 1 | 20.2 | 21.3 | 20.3 |
| 09 | 37°02.03'N | 075°19.6'W | CLR | BR | 10 | 180 | 12 | 1017.3 | <1 | 180 | 1-2 | 20.7 | 21.1 | 20.3 |
| 10 | 37°00.4'N | 075°29.9'W | CLR | BR | 10 | 185 | 13 | 1017.2 | 1 | 180 | 2 | 20.1 | 21.3 | 20.2 |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | 36°59.4 | 76°18.70 | CLR | -BR | 10 | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | |



SUPERSEDES NOAA Form 77-13D (3-76)

# TJ Static Draft

G. Rice, E. Younkin
Hydrographic Systems and Technology Branch
2016-10-12

## Introduction

With her very large fuel capacity, *Thomas Jefferson's* operational draft varies considerably over the course of a survey season. The draft of the reference point has historically been measured with a flexible water level sight tube. However, procedures for measuring and recording this value have not been well defined. To improve this process, a Sutron bubbler water level gauge was installed in 2014 to replace manual sight tube readings. In this report, we discuss the Sutron water level gauge and analyze data taken through gauge readings, draft mark readings and ellipsoidally referenced tide station data. We find all three systems of measurement to be acceptable, but the Sutron gauge provides the easiest and most precise measurement of static draft.

Manual Sutron and draft mark observations were made at 1140 and 1300 UTC and POS M/V data was recorded between these times. Through the use of the Autopoll software, one-minute interval Sutron data was also logged to a local computer. The Marinestar corrected POS MV data was processed in POSPac in forwards/backwards processing mode without the inclusion of base station data in order to generate an SBET. This SBET was used in the ellipsoidally referenced static draft script.

In this report, draft is defined as the distance from the reference point to the water surface with the positive direction down; when the reference point is above the water surface, as it typically is with *Jefferson* in all but her most heavily laden conditions, the draft will be a positive number. This is consistent with the sign conventions in both Caris and Kongsberg.

## Vessel Sensitivity to Loading

By examining the ship stability tables, the weight of the survey launches, and typical fuel burns, we can calculate the vessel's sensitivity to loading. At her design draft, the stability book indicates 190.6 long tons per foot submergence, or 14,000 lbs/cm submergence. This means that an additional 14,000 lbs of deck loading will cause the ship to sink into the water by 1 cm. Conservatively estimating the full, laden weight of a launch at 18,000 lbs, the draft change from either deploying or recovering both launches is approximately 0.025 m. The typical daily fuel burn at survey speed (approximately 1600 gallons per day), will result in a draft change of less than 0.01 m per day or less than 0.06 m per week. Accordingly, we recommend updating the draft value in the HVF no more than once a week during survey operations.

## Sutron Installation and Configuration

The Sutron bubbler water level gauge, similar to the NOAA field unit installed water level gauges, uses compressed gas to carry the static pressure at a submerged orifice to the pressure gauge in the instrument. This configuration allows the pressure sensor to be both dry and also be balanced against the atmospheric pressure such that variations in atmospheric pressure can be neglected in the determination of the water level head pressure. A photo of the sea-valve and orifice configuration is shown in Figure 1. With the vent valve open, the measured pressure is at the level of the orifice indicted by the arrow. This offset was measured by IMTEC in 2016 as 3.908 meters with respect to the IMU reference point [1]. With the vent valve closed, the effective orifice is the penetration in the shell plating. The offset to the shell plating was not accurately measured during the installation. In normal operations, the vent valve should be left open.

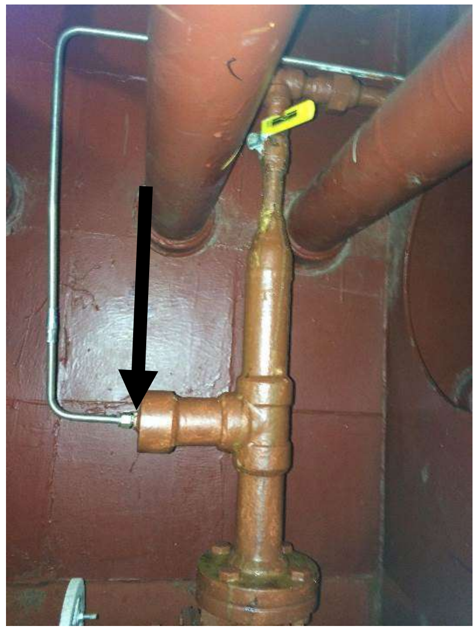


*Figure 1: Bubbler gauge orifice and vent line. Vent valve has yellow handle and should be OPEN. Arrow indicated surveyed position of orifice and the location of the measured draft.*

In general, conversion of a pressure measurement to a depth requires knowledge of the density of the water and the local gravitational attraction. The general equation of the height of the reference point above the water level is given below. This is the value (with correct sign) used in the 'waterline' section of the Caris HVF and in Kongsberg SIS.

$$wl = -PSI\,\frac{6894.7\,Pascal/psi}{\rho * g} - orificeZ \qquad (1)$$

where *wl* is the height of the reference point above the waterline, $\rho$ is water density in kilograms/ meter$^3$, g is the acceleration due to gravity, and *orificeZ* is the surveyed distance from the reference point to the bubbler orifice. The gravitational acceleration, 9.79819 m/s$^2$, was calculated from the WGS84 Gravity Model for latitude 36. For these small depths, the effect of the variability of gravity is negligible, accounting for an effective draft error of less than 0.01 m for latitude changes between 0 and 60 degrees. The density effect is more significant, with a variation from fresh to salt water yielding a difference of approximately 0.08 m for this system. Using typical sea-surface water density of 1024 kg/m$^3$, the formula for the height of the reference point above the water line is given by:

$$wl = -0.68718(\mathrm{PSI}) + 3.908 \qquad (2)$$

These figures have been entered into the custom fields of the bubbler gauge (station setup/ accubar setup/ accubar settings/ user slope and user offset) such that the output value is the meters of the reference point above the waterline (note that when the ship is fully laden, the reference point may be below the water line and this number will then be negative).

On April 17, 2015 (Dn107) a series of six water level measurements were made from the IMU to the level in a sight tube. A laser was set on the top of the IMU and a ruler used to measure the distance from the top of the IMU to the water level in the sight tube. The reading was corrected for the height of the laser. The water level was 0.285 ± 0.004 meters relative to the reference point. That afternoon, a CTD cast measured a density of 1012 kg/m$^3$ in the brackish waters of the Elizabeth River. Using this density, the observed pressure of 5.182 psi on the bubbler gauge, and equation (2) above, the bubbler derived waterline height is 0.305 meters, yielding an error of 0.02 m. The source of this error is unknown, but is within tolerance for hydrographic survey work.

Unless extended survey operations are planned for fresh waters (e.g. the Great Lakes), we recommend the standard density of 1024 kg/m$^3$ be used for the calculation of waterline and the custom offsets retained as entered. In brackish waters, the reported draft variation with density may be significant enough to consider for precise calibration work, though can likely be neglected for routine survey work. In the case were additional precision is required, we recommend calculating the waterline from the observed pressure and observed density using equation (1) to derive the height.

## Sutron Results

Readings were taken from the Sutron at the beginning and end of observations at 0.385 meters and 0.351 meters respectively. The readings were also recorded via AutoPoll every minute into CSV files and displayed in Figure 2. Again, these readings are the water level relative to the IMU as the bubble gauge offset from the IMU, 3.908 meters, was entered into the Sutron. The mean of this time series is 0.37 meters with 0.02 at two standard deviations.

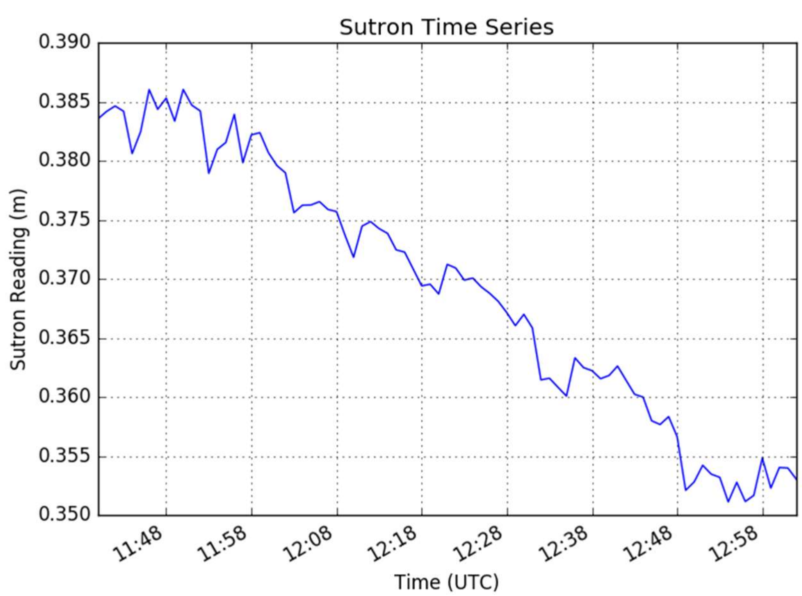



*Figure 2 - The Sutron time series.*

There is a clear trend in the Sutron data. When an extended time series is plotted it appears that the static draft test was conducted during an inopportune time as displayed in Figure 3. After discussing this anomaly with the ship, we learned that ballast was taken on at approximately 1100 UTC to achieve an additional few inches of draft astern. We can see that a change of about 3.5cm was seen in the Sutron derived waterline value. Using the previously mentioned 14,000 lbs/cm loading estimate, we can say that about 49,000 lbs or about 21.71 cubic meters of sea water was taken on during this period.

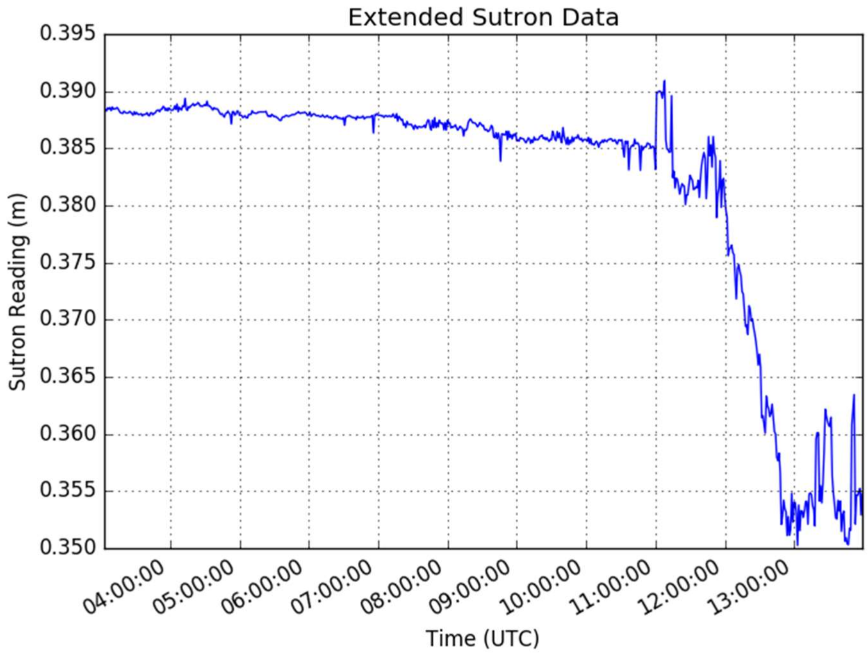



*Figure 3 – The Sutron time series from 2016-10-12 for a period before and after the static draft test.*

## Draft Mark Results

The transom and bow (port side) draft marks were observed from the wharf at the times described. The draft did not change at an observable amount over this time, with the transom reading 13.9 feet and the bow (port side) reading 13.8 feet. This finding, along with our internal understanding of the accuracy of draft mark readings, led to our assumed two standard deviation of 0.07 cm. A weighted average was used to estimate the draft at the horizontal location of the IMU, which is closer to the bow. This average, 13.83 feet, was then converted to meters and referenced to the IMU using an IMU to keel offset derived from the raw survey values from the ship offset survey conducted in August of 2016 [1]. This offset was derived by averaging the keel vertical offset observations after the values were referenced to the IMU, with a result of 4.56 meters. The final result, 0.34 meters, with this derivation from the draft marks is shown in Table 1.

*Table 1 - Draft of the reference point from draft mark readings*

| TJ Static Draft | |
|---|---|
| | Reading (Feet) |
| Bow - PORT | 13.8 |
| Transom | 13.9 |
| | |
| Average Reading (Feet) at estimated reference point | 13.83 |
| Average Reading (Meters) at estimated reference point | 4.22 |
| Approximate Standard Deviation (2 sigma) | 0.07 |
| IMU to Keel offset | 4.556 |
| Waterline relative to the IMU (RP) | 0.336 |

## Ellipsoid Referenced Static Draft Results

A POS MV file was recorded during the time period described and processed in POSPac using forwards/backwards processing without the inclusion of any base station data. While some attempt was made to understand the waterline offset from the AutoQC tool in Pydro, eventually the ERSD script, also in Pydro, was used instead. This approach results in a poorer tide correction since the phase and amplitude at the Atlantic Marine Operations Center from the local tide gauges is not taken into account. The script was run twice, once for the Money Point tide gauge, 8639348, and again for the Sewell's Point tide gauge, 8639610.

The ERSD script references the water levels to the ellipsoid using a provided offset from the water level data to the ellipsoid. The water levels are then subtracted from the ellipsoid height of the ship, with the resulting value being the reference point draft over time. These values are then averaged for a final estimate. More information on the ERSD script can be found in [2].

The Money Point gauge reference resulted in a mean draft of 0.43 meters with two standard deviations being 0.07 meters as reported by the script in Figure 4. The offset from mean lower low water to WGS84 provided by VDatum for the Money Point gauge was -39.0014 meters.

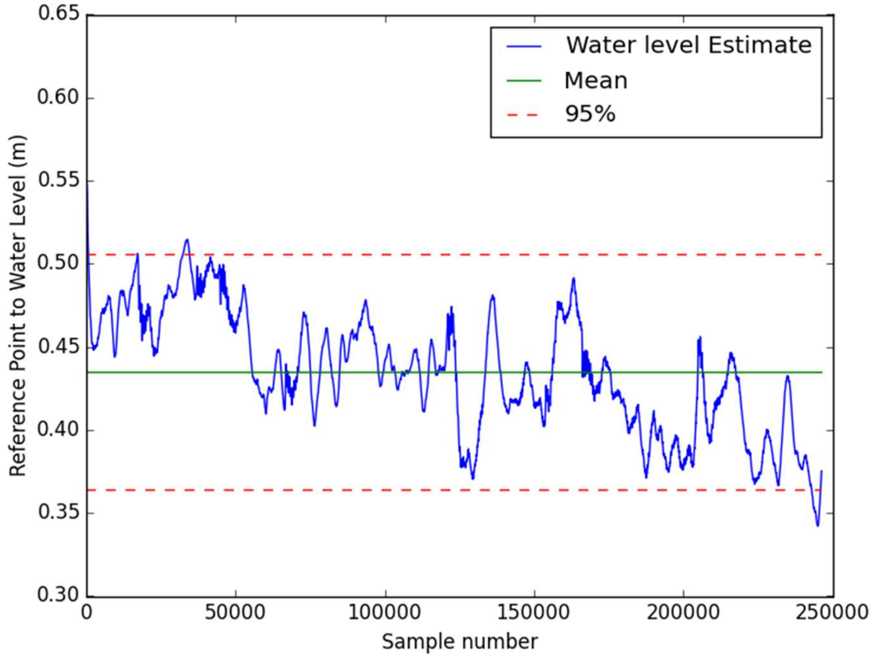



*Figure 4 - SBET values relative to the ellipsoid referenced water levels from Money Point over the time period.*

The Sewell's Point gauge reference resulted in a mean draft of 0.32 meters with two standard deviations being 0.08 meters as reported by the script in Figure 5. The offset from mean lower low water to WGS84 provided by VDatum for the Sewell's Point gauge was -38.7367 meters.

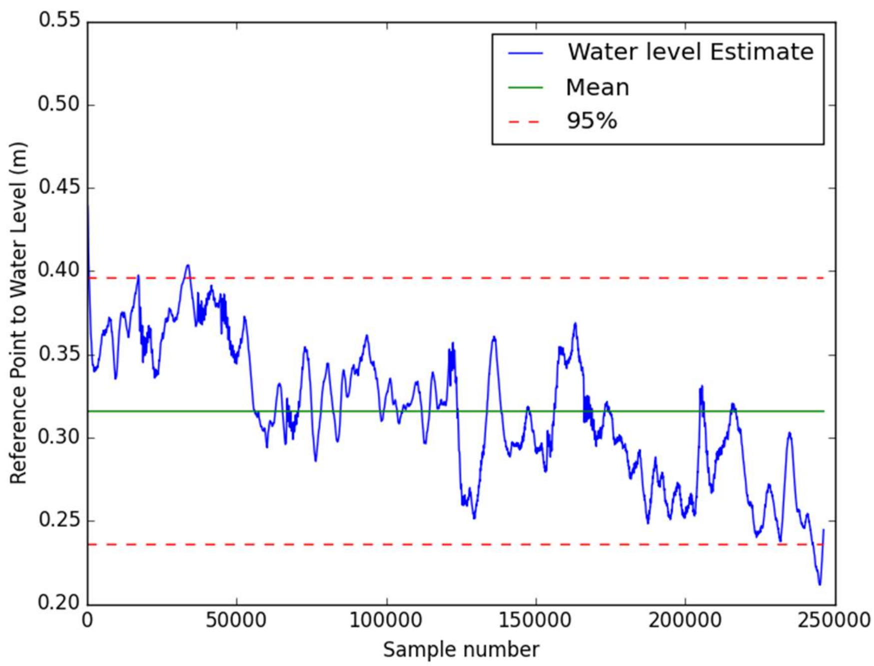



*Figure 5 - SBET values relative to the ellipsoid referenced water levels from Sewell's Point over the time period.*

## Conclusion

The draft of the reference point from the different approaches is summarized in Table 2.

*Table 2 – A summary of the static draft estimates.*

| Source | Result (Meters) | 2 Standard Deviations (Meters) |
|---|---|---|
| Draft Readings | 0.34 | 0.07 |
| Sutron | 0.37 | 0.02 |
| ERSD – Money Point | 0.43 | 0.07 |
| ERSD – Sewell's Point | 0.32 | 0.08 |

No final value is derived as the static water level changes with loading conditions. Instead this series of tests confirms that each method arrives at a statistically equivalent value, and any of them could be used. That being said, only the ERSD and Sutron method are precise enough to even see the 3.5cm change in draft during the testing period. This is to be expected, as that frequency and precision of both POS MV and tide gauge measurements far surpasses the draft readings and that change was well within the variability of the draft reading measurement. For its simplicity and precision, the Sutron gauge is the recommended method for estimating the ship's static water level. The Sutron should only be used when the ship is dead in the water as water flowing over the hull will affect the measurement.

## References

[1] "NOAA Thomas Jefferson (S 222) Sensor Alignment & Orthogonal Coordinate Survey July-August 2016, Rev 1," The IMEC Group, Ltd, 2016

[2] G. Rice, "Estimating Vessel Static Waterline Using Vessel Ellipsoid Height," NOAA Office of Coast Survey, Silver Spring, MD, Tech Rep. 2011

# NOAA Ship Thomas Jefferson CARIS HIPS 9.1 Post Processing Workflow for the EM2040

HSTB, December 7, 2016

## Purpose

NOAA Ship *Thomas Jefferson's* survey system is configured differently than other Kongsberg systems in the NOAA hydrographic fleet. Most notably, the primary reference point for the survey system is placed at the IMU rather than the multibeam transmit transducer because *Thomas Jefferson* has two multibeam systems; one POS MV configuration works for both. Also of note, *Thomas Jefferson* has a MarineStar license and can thereby use the ellipsoid height stored in the Kongsberg data directly without the need for POSPac post processing.

Because of how the reference point- transmitter lever arm is accounted for in Caris, there is no one HVF and processing configuration that can accommodate the various possible processing paths (e.g. using real-time Marinestar height and SIS raytracing to convert and merge in Caris without sound velocity correction (SVC), applying delayed heave and a new sound speed profile in Caris and using a tide corrector, etc.). Each of these processing paths can be accommodated, but many require different HVF configurations and processing parameters. Please contact HSTB for additional details if interested.

The recommended workflow options below have been formulated and tested by HSTB. While the required steps making up each method may be less efficient than possible for a given approach, this affords the most flexibility for data processing under one HVF. ***This HVF is named S222_EM2040_HSTB.hvf***.

***The methods require application of the POS M/V TrueHeave (delayed heave) data and requires computing the SVC in CARIS HIPS; the latter is mandatory regardless of whether new sound speed information or calculations beyond that used in Kongsberg SIS data acquisition are available or desired. Specifically, these steps are required for both the real-time ellipsoid-referenced survey (ERS) processing method and the traditional water levels processing method, as detailed below***.

## Method

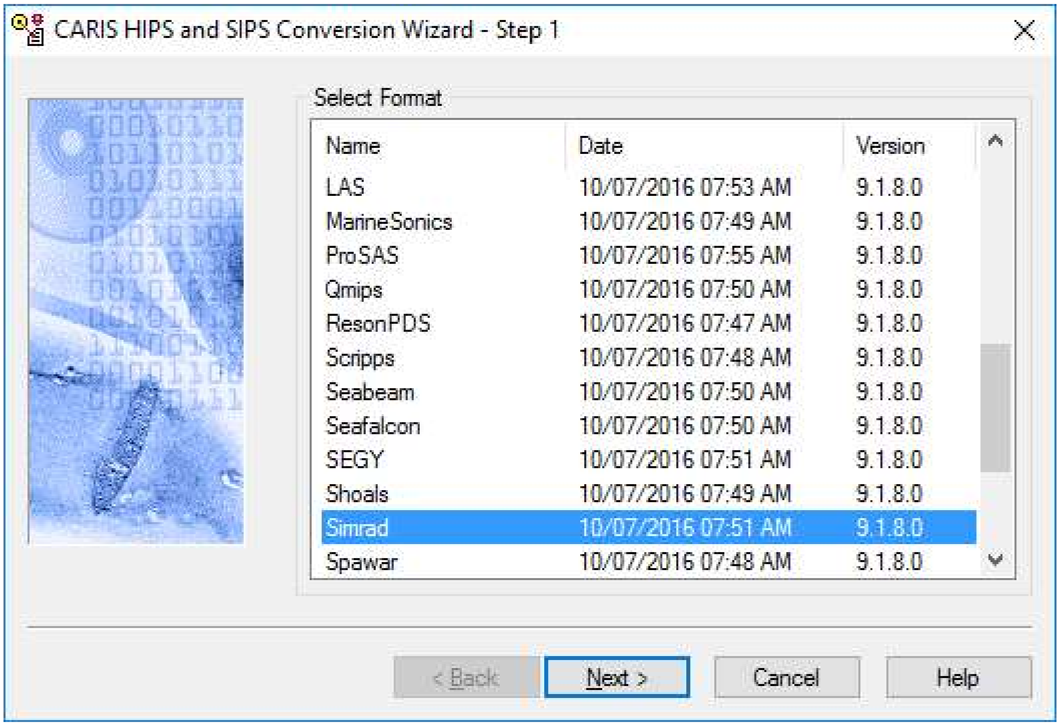
The two methods are as follows:

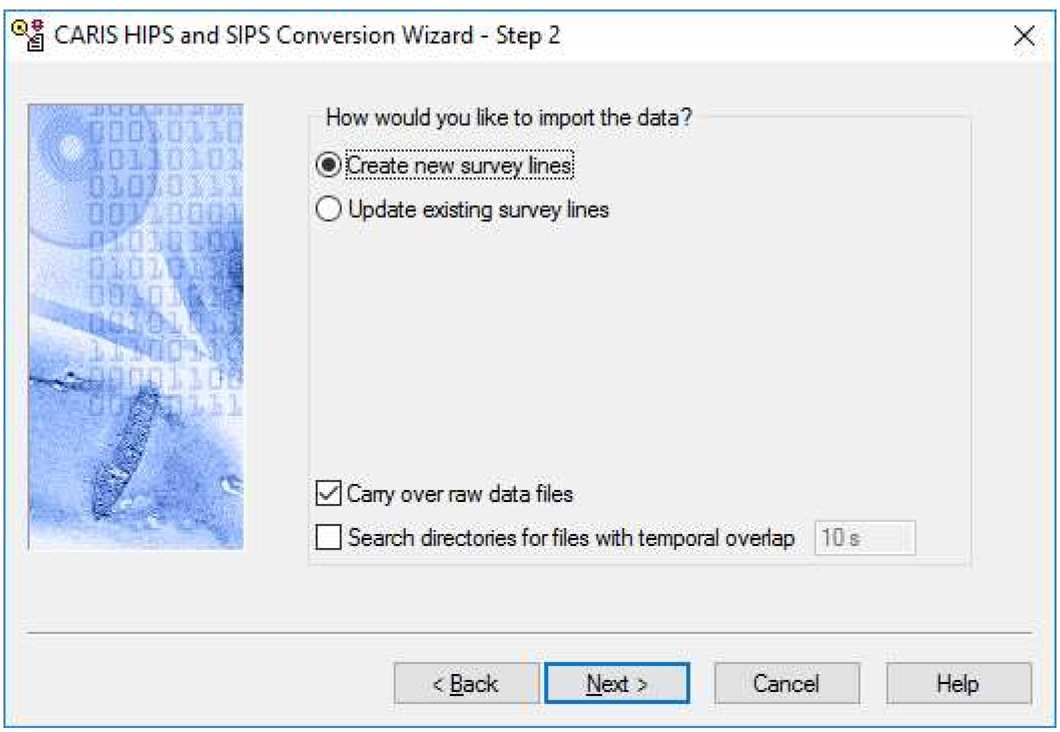
1) ERS
    a. Convert MBES data → Load Delayed Heave → Sound Velocity Correct → Compute GPS Tides → Merge with GPS Tides → TPU

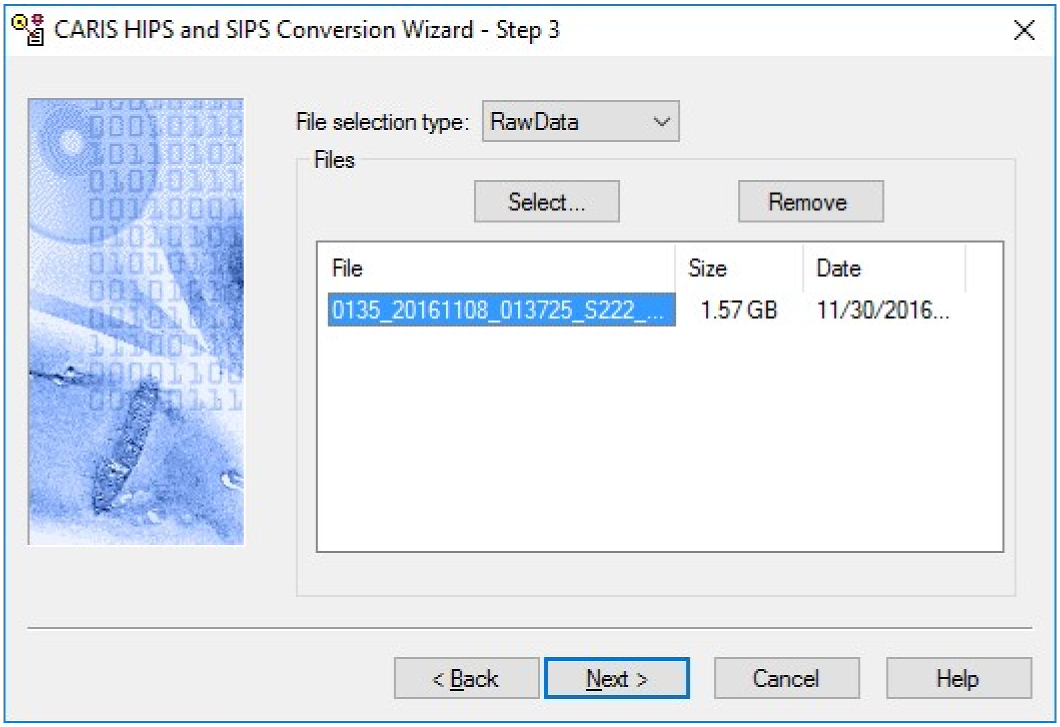
2) Traditional Water Levels
    a. Convert MBES data → Load Delayed Heave → Load Tides → Sound Velocity Correct → Merge → TPU

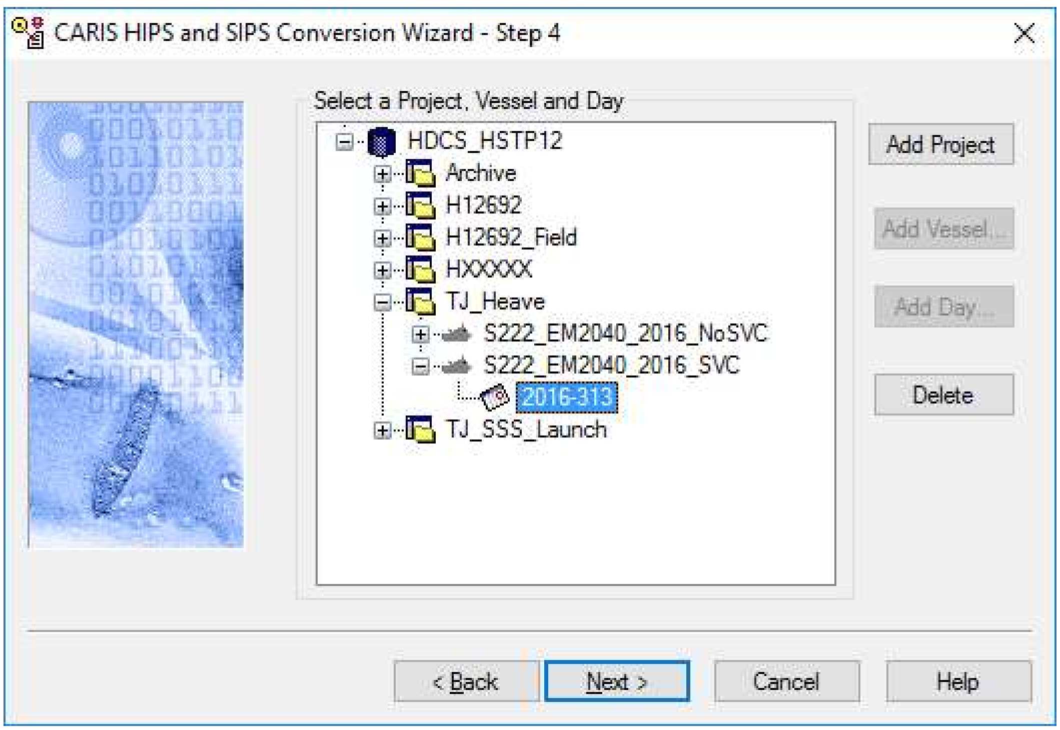
## Procedure

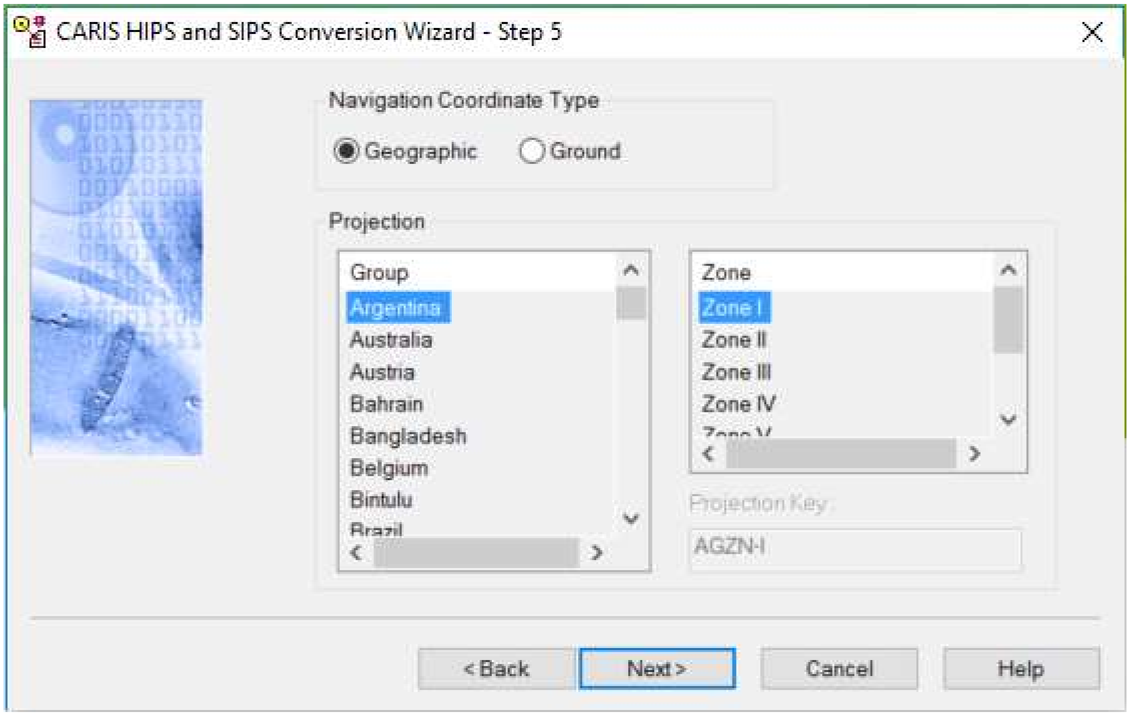
### Conversion (both methods, 1 and 2)

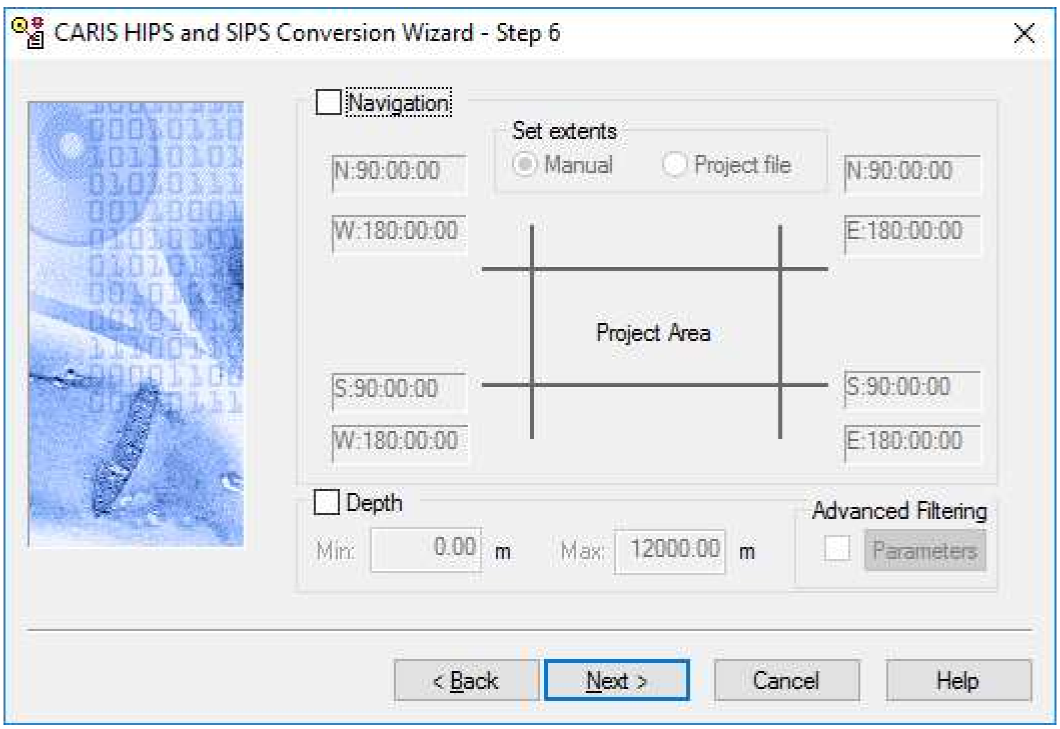


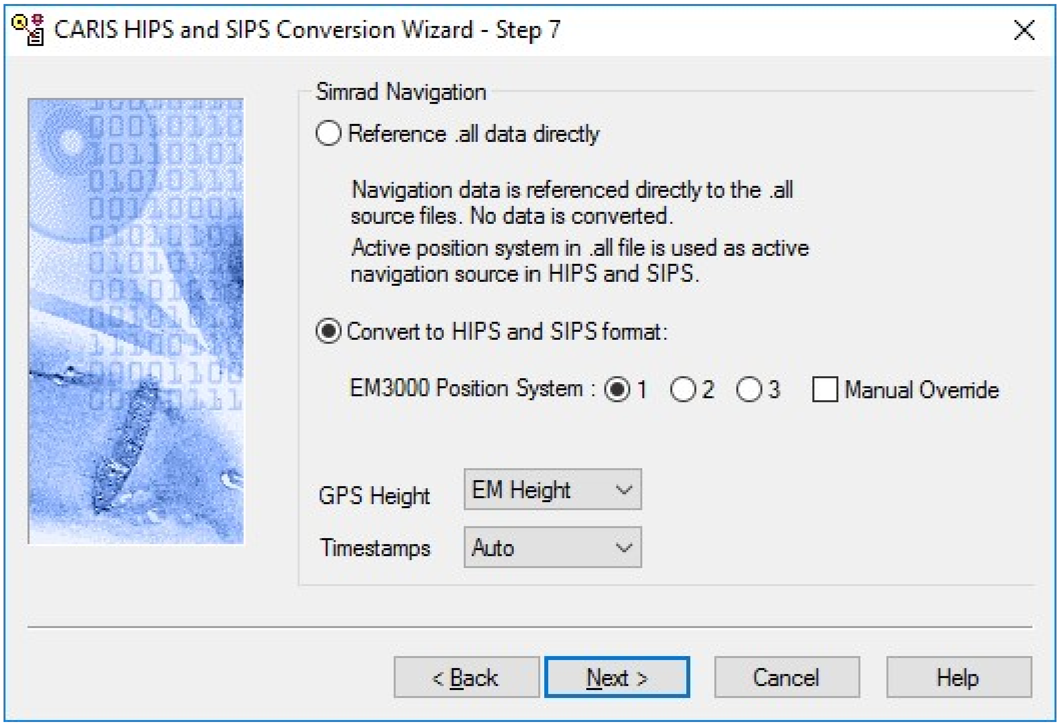

CARIS HIPS and SIPS Conversion Wizard - Step 3
File selection type:
RawData
Files
Select...
Remove
File
Size
Date
0135_20161108_013725_S222_...
1.57 GB
11/30/2016...
< Back
Next >
Cancel
Help

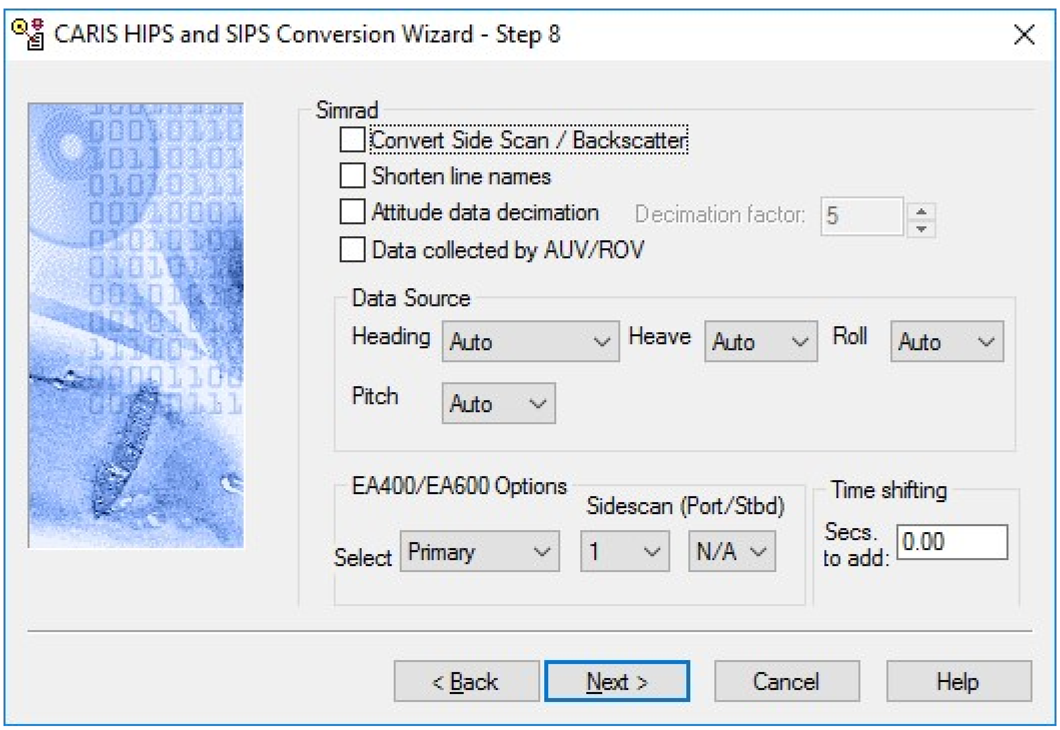

CARIS HIPS and SIPS Conversion Wizard - Step 4
Select a Project, Vessel and Day
HDCS_HSTP12
Archive
H12692
H12692_Field
HXXXXX
TJ_Heave
S222_EM2040_2016_NoSVC
S222_EM2040_2016_SVC
2016-313
TJ_SSS_Launch
Add Project
Add Vessel...
Add Day...
Delete
< Back
Next >
Cancel
Help

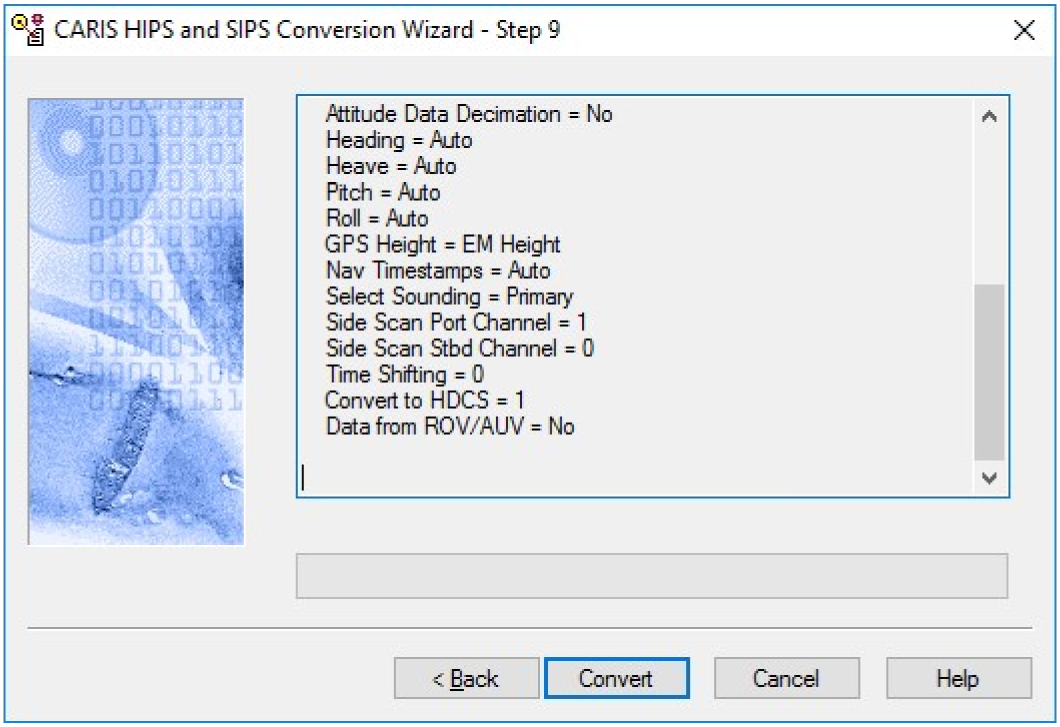

CARIS HIPS and SIPS Conversion Wizard - Step 5
Navigation Coordinate Type
Geographic
Ground
Projection
Group
Argentina
Australia
Austria
Bahrain
Bangladesh
Belgium
Bintulu
Zone
Zone I
Zone II
Zone III
Zone IV
Projection Key
AGZN-I
< Back
Next >
Cancel
Help


CARIS HIPS and SIPS Conversion Wizard - Step 6
Navigation
Set extents
Manual
Project file
N:90:00:00
W:180:00:00
N:90:00:00
E:180:00:00
Project Area
S:90:00:00
W:180:00:00
S:90:00:00
E:180:00:00
Depth
Min: 0.00 m
Max: 12000.00 m
Advanced Filtering
Parameters
< Back
Next >
Cancel
Help

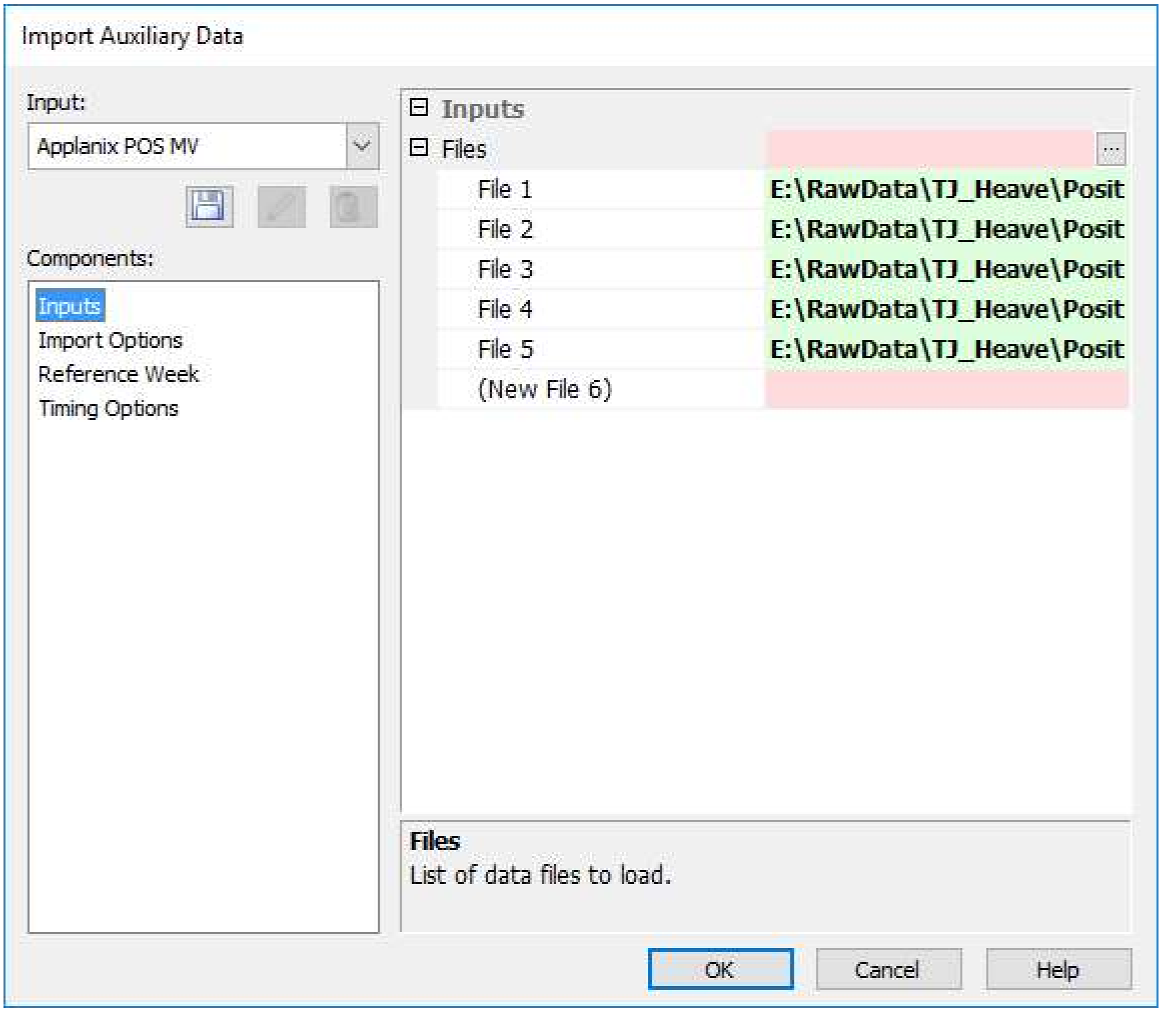
Data sources are set to "Auto" in the following dialogues because CARIS conversion algorithms are capable of reading the .all file (and other file types; ie: hsx) and determining data source.

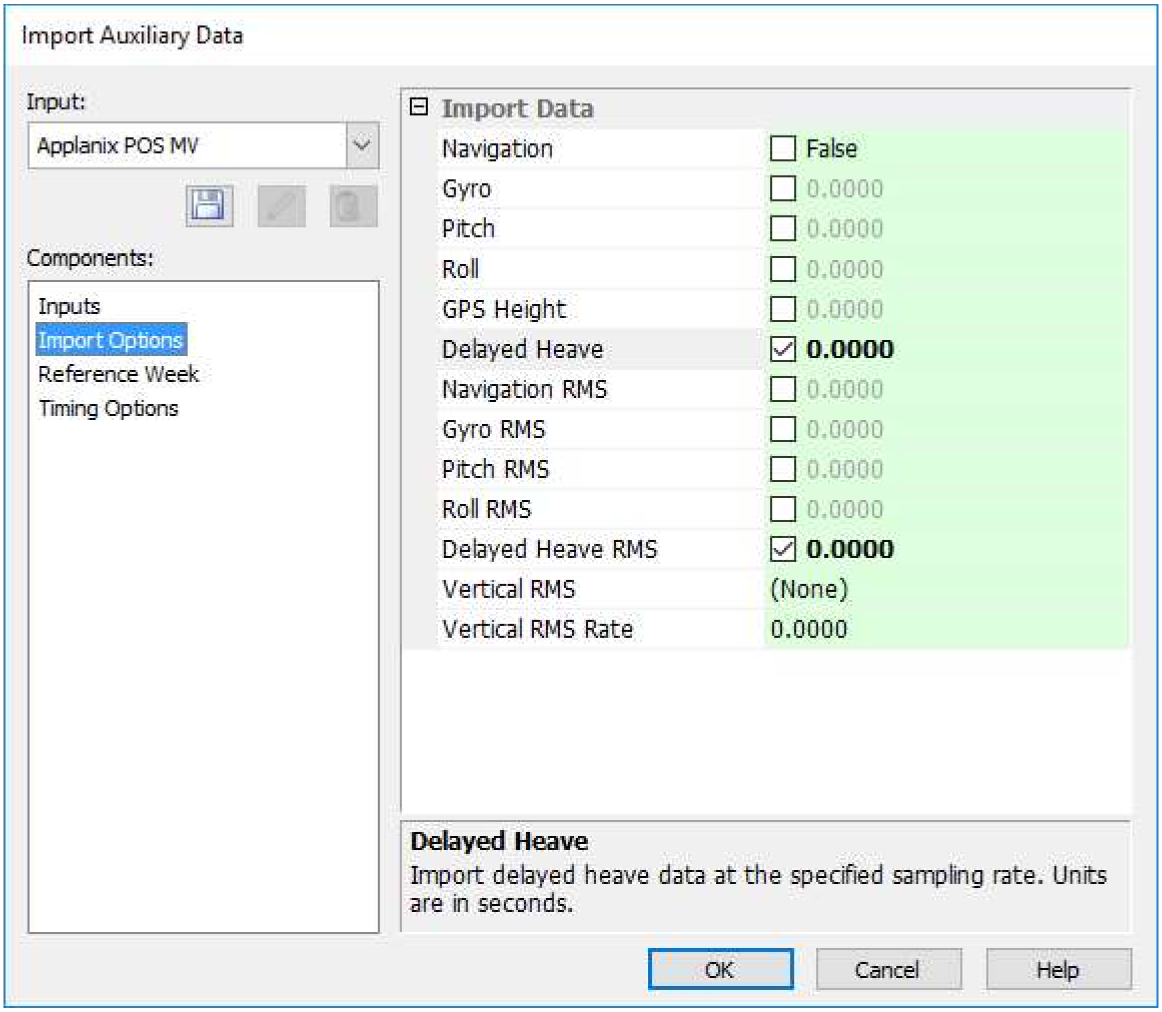


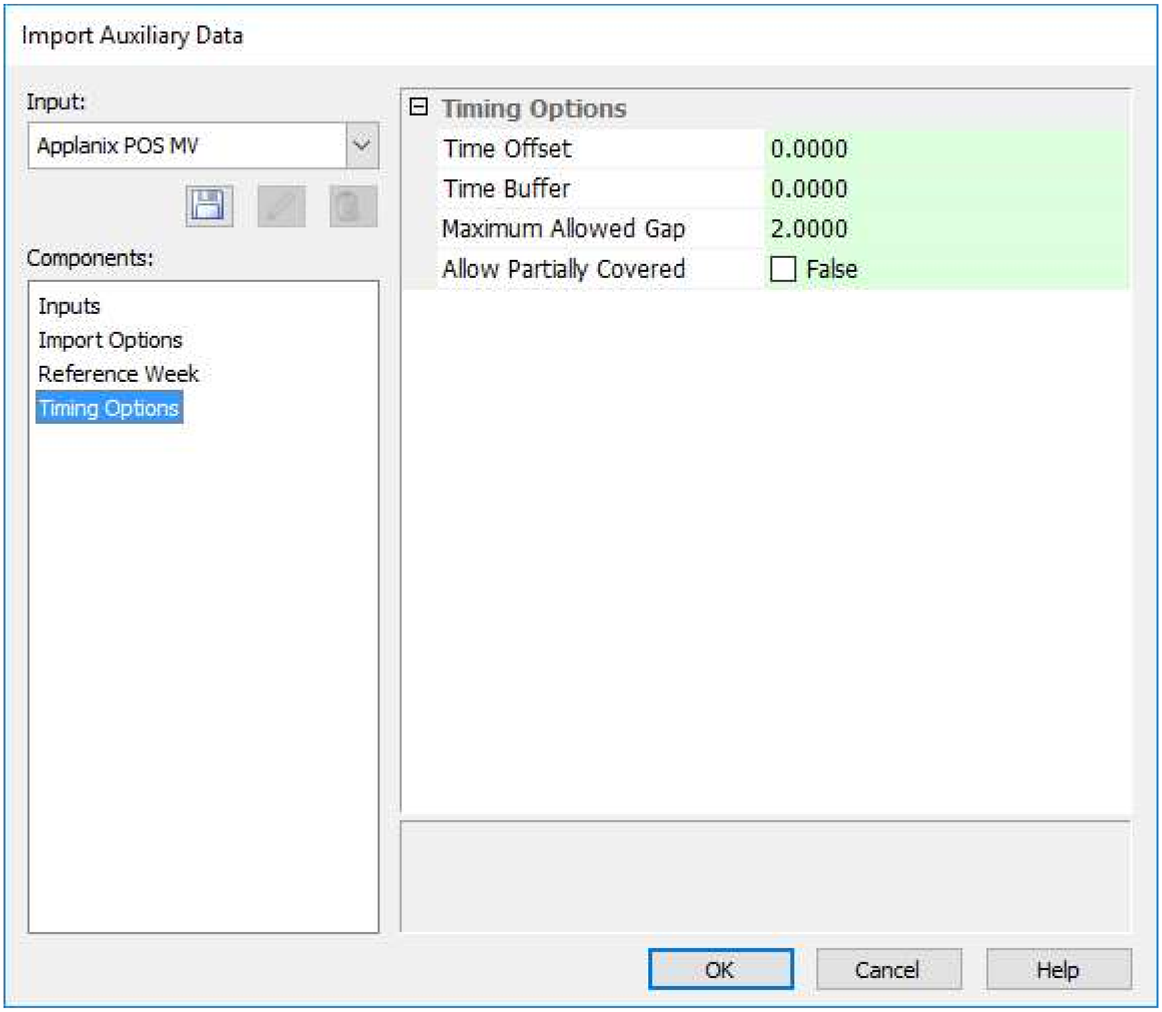




CARIS HIPS and SIPS Conversion Wizard - Step 9
Attitude Data Decimation = No
Heading = Auto
Heave = Auto
Pitch = Auto
Roll = Auto
GPS Height = EM Height
Nav Timestamps = Auto
Select Sounding = Primary
Side Scan Port Channel = 1
Side Scan Stbd Channel = 0
Time Shifting = 0
Convert to HDCS = 1
Data from ROV/AUV = No
< Back
Convert
Cancel
Help

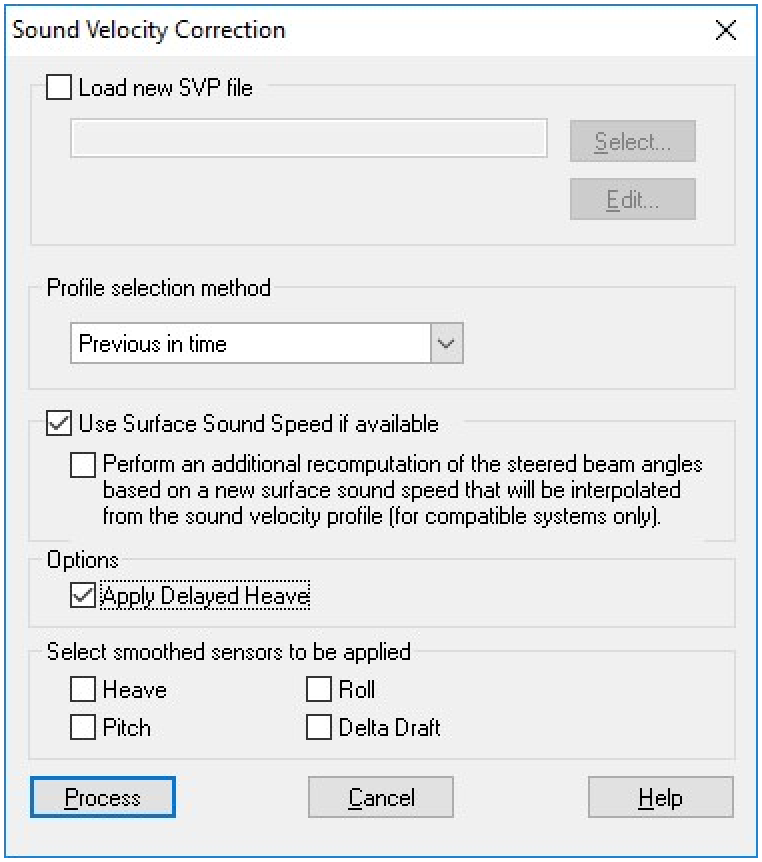
## Import Delayed Heave (both methods, 1 and 2)




Import Auxiliary Data
Input:
Applanix POS MV
Components:
Inputs
Import Options
Reference Week
Timing Options
Import Data
Navigation
False
Gyro
0.0000
Pitch
0.0000
Roll
0.0000
GPS Height
0.0000
Delayed Heave
0.0000
Navigation RMS
0.0000
Gyro RMS
0.0000
Pitch RMS
0.0000
Roll RMS
0.0000
Delayed Heave RMS
0.0000
Vertical RMS
(None)
Vertical RMS Rate
0.0000
Delayed Heave
Import delayed heave data at the specified sampling rate. Units are in seconds.
OK
Cancel
Help


Import Auxiliary Data
Input:
Applanix POS MV
Components:
Inputs
Import Options
Reference Week
Timing Options
Timing Options
Time Offset
0.0000
Time Buffer
0.0000
Maximum Allowed Gap
2.0000
Allow Partially Covered
False
OK
Cancel
Help

While a new sound speed profile does not need to be added in this step, the SVC step is required for these workflows. By leaving the “Load new SVP file” box unchecked, CARIS will use the SV profiles embedded in the raw data per the .all file. Apply Delayed Heave is selected so that lever arm corrections are performed accurately. If Delayed Heave is not selected in this step, then a heave artifact will be introduced in the processed data.



GPS Tides is a method for computing the ellipsoid height of the vessel such that the bathymetry can be referenced to the ellipsoid. SVC'd depths are compensated for motion and are relative to the static water level. Because the converted vessel GPS Height (Kongsberg ,all EM Height) includes the water line offset and motion, in Compute GPS Tide we answer: *False* to Water Line, but apply=*True* to both the Dynamic Draft (to match the HVF) and the Dynamic Heave (Delayed Heave). The following list summarizes the options accounting required in Compute GPS Tides for the Thomas Jefferson EM2040.

-Smooth GPS height is not selected because we want to use the observed GPS Height.

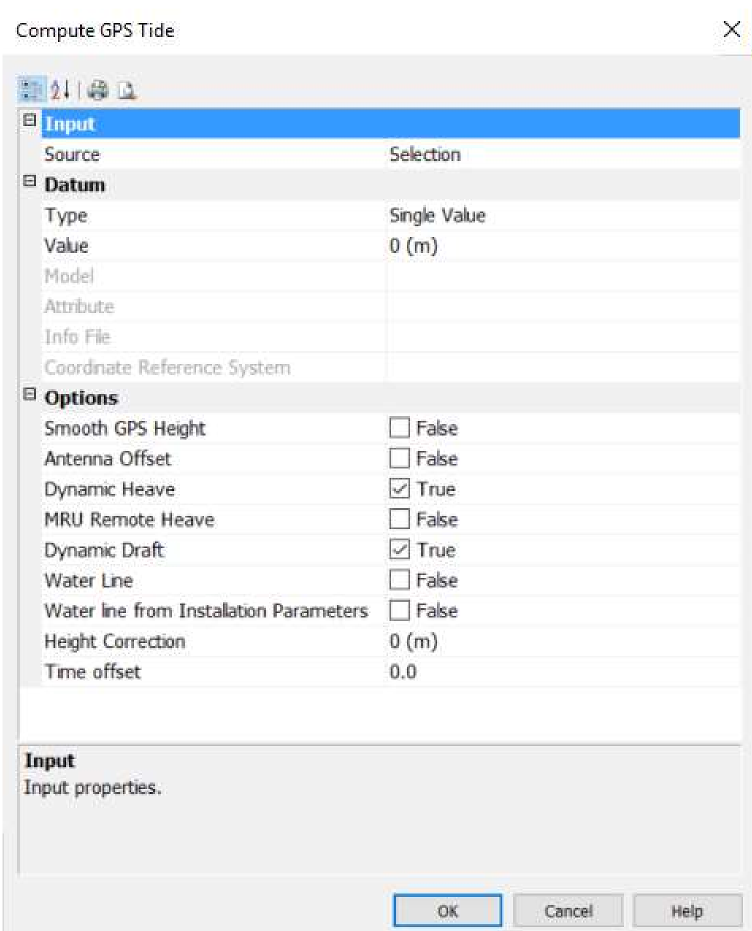
- Antenna offset is not selected because offsets from GPS antennas to the IMU accounted for in POS M/V

-Dynamic Heave is applied in order to remove heave from the observed GPS Height, smoothing the time series the same way that accounting for heave smooths the bathymetry.

-SIS is not accounting for lever arm offsets to the transducer from IMU with the GPS height, so the GPS Height is at the IMU as is Delayed Heave in the POS M/V file. Thus MRU Remote Heave is not selected because our RP is the IMU; moment arms are identically zero.

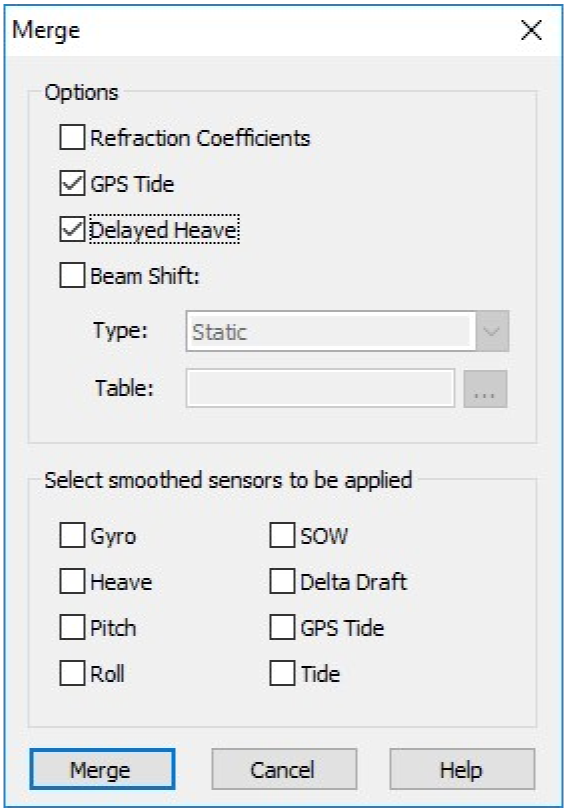
-Dynamic Draft (DD) is selected for congruence with HVF; DD is applied to the bathymetry per the HVF, so the GPS Height must be compensated to match.

-The dynamic GPS Height values in the .all file (EM Height, per conversion) are offset from the IMU by the water line as defined in SIS. Waterline is not applied because the SVC'd depths account for the waterline, per introductory paragraph in this section.

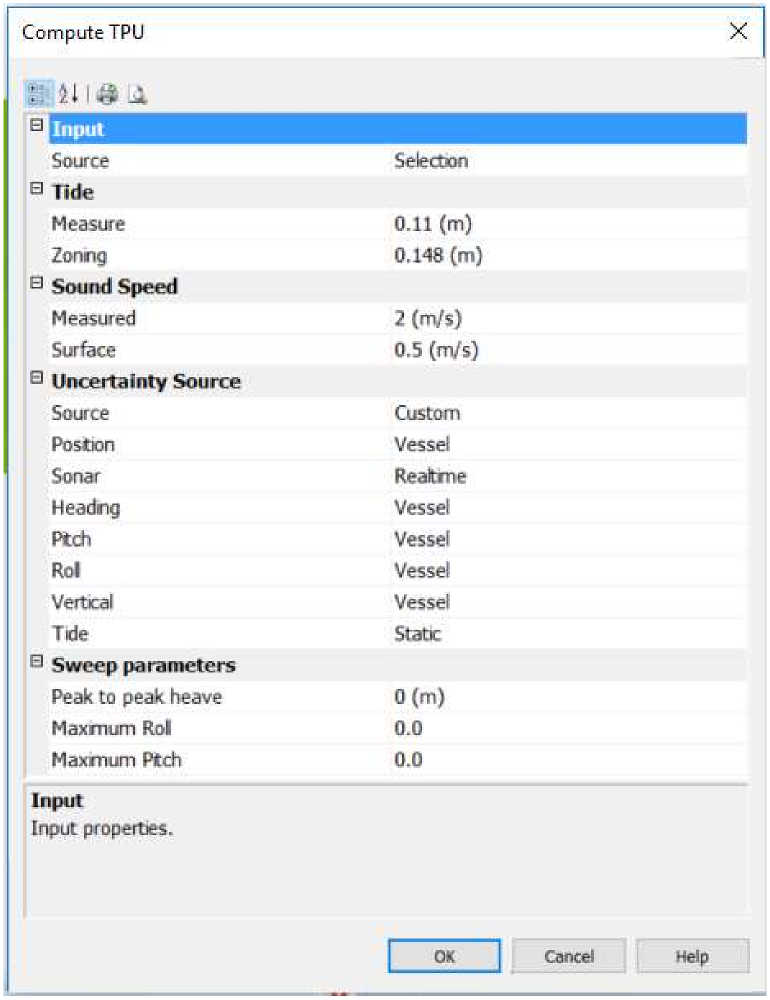


## Merge and Compute TPU - Method 1 (ERS)

Calculates the final position for soundings based on observed depths and applied corrections in post-processing. Select GPS Tides because this is an ERS processing method, and Delayed Heave as needed to match our application of the same in during our *mandatory* SVC, described above.

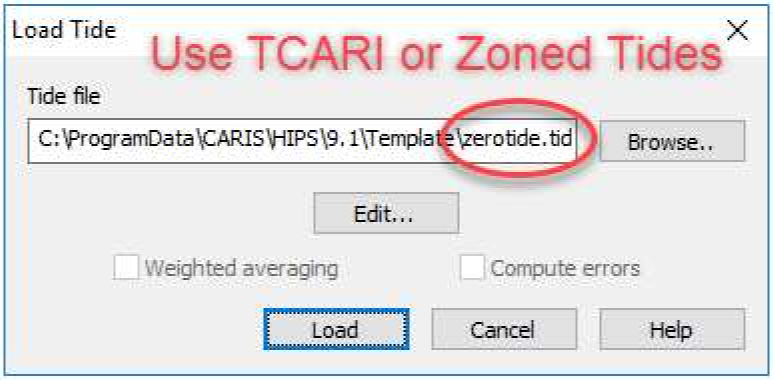


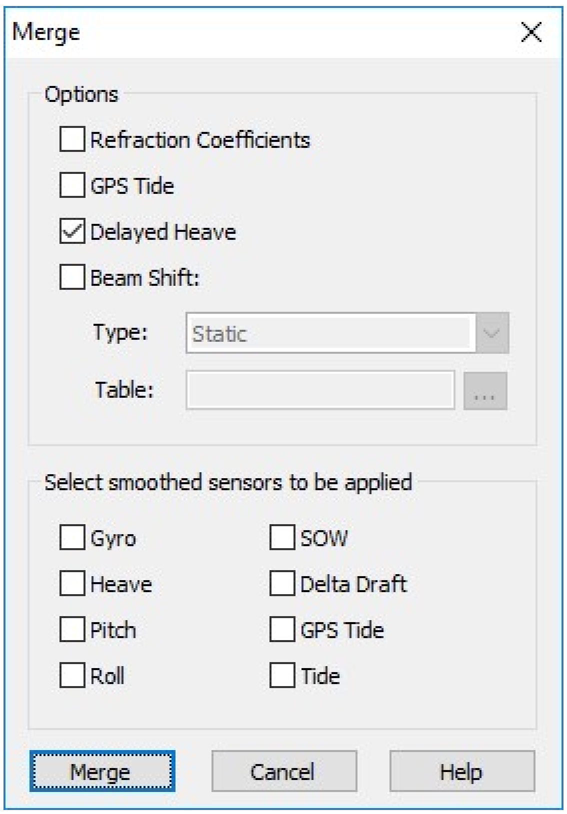
TPU for the vertical datum when surveying to the ellipsoid is a variance summation of the uncertainties associated with (1) MarineStar-aided POS MV height and (2) the datum separation (SEP) model. The MarineStar uncertainty is placed in the Tide / Measured section of the TPU dialog as 0.11 meters. The SEPuncertainty is placed in the Tide / Zoning section of the TPU dialog and is survey area-specific as provided in Project Instructions (e.g., for OPR-G329-TJ-16/17, VDatum SEP StdDev=0.148m). Sonar uncertainty is per the converted Realtime Kongsberg metrics from the .all. All other uncertainty sources are set to zeros via the HVF; see the Method 2 – Traditional Water Levels Compute TPU section for more information regarding this.



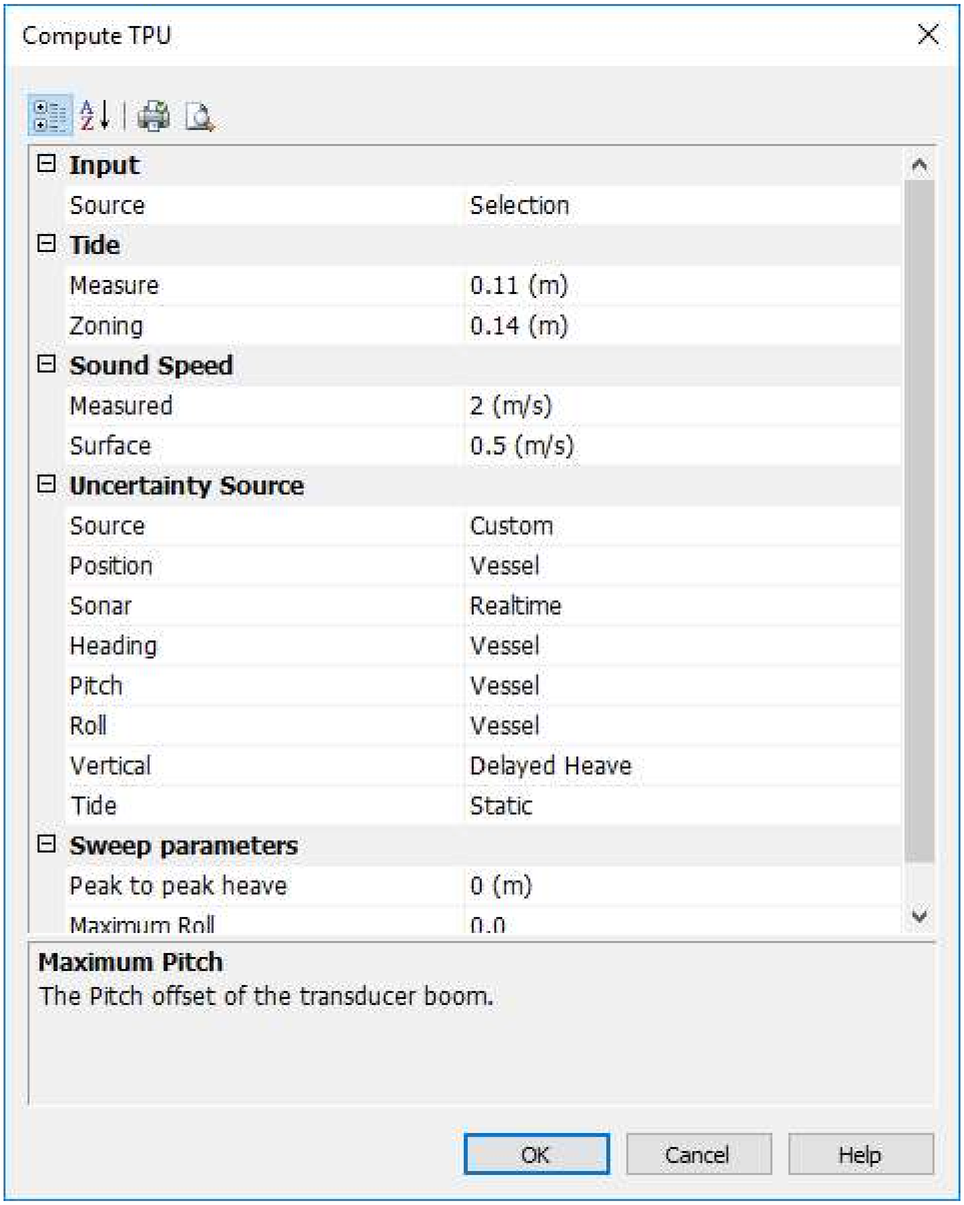

```
====== ComputeTPU start: Dec 7, 2016 8:00:36 AM ======
E:\ProcData\HDCS_Data\TJ_Heave\S222_EM2040_2016_SVC\2016-313\0135_20161108_013725_S222_EM2040. The following error sources were applied:
Warning: Realtime gyro errors not available. Vessel settings used instead.
Warning: Realtime pitch errors not available. Vessel settings used instead.
Warning: Realtime roll errors not available. Vessel settings used instead.
Warning: Realtime position errors not available. Vessel settings used instead.
Warning: Realtime tide errors not available. Static values used instead.
        Sonar: Realtime data
        Position: Vessel settings
        Gyro: Vessel settings
        Heave: Realtime Delayed Heave
        Pitch: Vessel settings
        Roll: Vessel settings
        Tide: Static values
====== ComputeTPU end: Dec 7, 2016 8:00:57 AM (Elapsed Time: 00:00:21) ======
```

### Load Tide, Merge and Compute TPU - Method 2 (Traditional Water Level Corrections)




Normal practice in the traditional water level method is to enter the uncertainty values attributed to vessel speed (0.03m), loading (0.06m), draft (0.03m), and delta draft (0.05m) in the HVF TPU StdDev, for Compute TPU Uncertainty Source = Vessel look-up. Our workflow sets them to zero in the HVF to account for our preference for one HVF for both non-ERS and ERS processing. For the Method 2 (Traditional Water Levels) we instead account for the aforementioned components as a single variance summation (root sum square; RSS=0.09m) and place that in the “Tide / Measured” slot. The actual (total) tide error component as provided in section 1.3.3 of the Project Instructions is placed in the Tide / Measured value (e.g., for OPR-G329-TJ-16/17, ZDF Tides StdDev = 0.10m). For TCARI-based projects, an average uncertainty value will be provided in the PI as well (e.g., OPR-E350-TJ-16, TCARI mean StdDev = 0.07m; OPR-D302-TJ-16, TCARI mean StdDev = 0.22m).




```
====== ComputeTPU start: Dec 7, 2016 8:30:55 AM ======
E:\ProcData\HDCS_Data\TJ_Heave\S222_EM2040_2016_SVC\2016-314\0135_20161108_013725_S222_EM2040.  The following error sources were applied:
Warning: Realtime tide errors not available.  Static values used instead.
        Sonar: Realtime data
        Position: Realtime data
        Gyro: Realtime data
        Heave: Realtime Delayed Heave
        Pitch: Realtime data
        Roll: Realtime data
        Tide: Static values
====== ComputeTPU end: Dec 7, 2016 8:31:17 AM (Elapsed Time:  00:00:21) ======
```

# NOAA THOMAS JEFFERSON (S 222)
# SENSOR ALIGNMENT & ORTHOGONAL COORDINATE SURVEY
# JULY-AUGUST 2016

# FINAL REPORT

September 1, 2016 - Rev "1"


Prepared By: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**I**ndustrial **M**easurement **T**echnology **E**ngineering **C**onsultants

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**ELECTRONIC FILES TRANSMITTED WITH THIS REPORT**

Raw Data-World.txt
Report Tables
- Kongsberg system.xlsx
- EM710TX system.xlxs
- IMU System.xlsx
- ORU System.xlsx

# PROJECT OVERVIEW

## Purpose

The purpose of this commentary is to summarize the procedures and analytical methods employed to perform the 3-D coordinate total station inspection that produced the data in this report for those unfamiliar with the equipment and process.

Dimensional data resulting from the inspection is included with the report.

## General Comments

This report summarizes coordinate measurement data taken on the vessel NOAA Thomas Jefferson July 27 and 28, 2016 and August 22 thru 26, 2016. The vessel was located in a graving dock at US Coast Guard Yard, 2104 Hawkins Point Road, Baltimore, MD.

Coordinate measurements were taken to characterize the vessel and create the required reference coordinate system for reporting azimuth, pitch, roll and coordinate data.

Coordinate measurements were then taken to define elements and features according to the SOW MOA2-11(15) Dated December 8, 2015 and as requested by NOAA representatives in support of the EM710 Multi-Beam Sounding system transducer installation.

Locations of existing draft marks were measured and recorded.

## 3-D Coordinate Measurement Equipment

A Sokkia NET 1200 enhanced electronic total station operated through a notebook computer running New River Kinematics Spatial Analyzer™ measurement and analysis software was utilized. This system measures 3-D spherical coordinates by recording an azimuth and zenith angle simultaneously with the near infrared distance coaxial with the telescope line of sight for each observation. Spatial Analyzer measurement and analysis software converts the spherical coordinate data to a Cartesian coordinate system that can be defined by the user. Measurements are made to either adhesive or kinematic targets that have a retro-reflective target face.

Temporary "benchmarks" or reference points were placed throughout the dry-dock area and on the vessel as required to allow for re-locating the instrument to a new position or "Station" and tie all of the data to the common coordinate system for comparison.

The measuring system used for this final inspection report is one of several owned by The IMTEC Group, Ltd. The NET 1200 total station, S/N 110554 was calibrated, traceable to N.I.S.T. and in accordance with A.N.S.I. Z-540-1, at the Sokkia USA Factory Service Center November 17, 2015.

## Reference Coordinate Systems

The following parameters were used to define the reference coordinate system for reporting the survey data per Kongsberg and NOAA representatives.

**Kongsberg requested vessel coordinate system:**

Origin: Top Dead Center (TDC) of the Inertial Measurement Unit (IMU):
X=0.000, Y=0.000, Z=0.000

Pitch and Azimuth:

Ten (10) Pairs of points were surveyed from approximately Frame 90 through Frame 10 on the Keel plate and then bisected to obtain a center point. These points were then projected onto the keel plane and used to construct a best fit line. A Best fit line faired through these points determined the ship system azimuth (X-Axis) and Pitch.

Roll: Six points were measured port/stbd, and fwd/aft and ~center port/stbd to determine the plane of the aft deck. This plane was used to establish roll.

Thus the vessel coordinate system is depicted as shown:

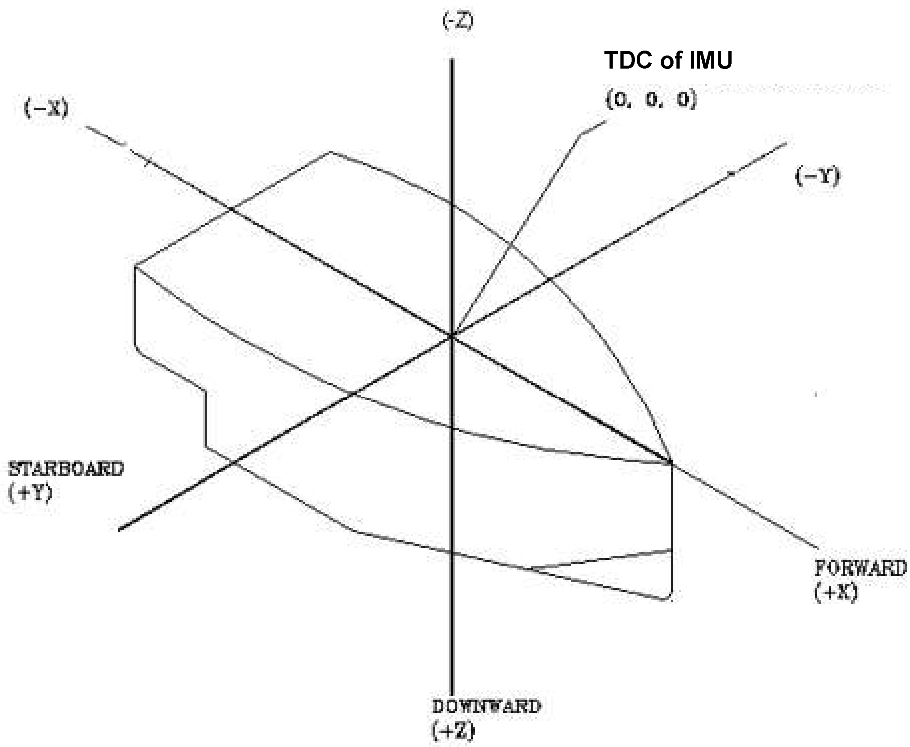


Figure 1 – Vessel Coordinate System

**The first coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | Center of TX Transducer Frame: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of TX Transducer Frame. |
| Roll: | Plane of TX Transducer Frame. |
| X Axis: | Azimuth of TX Transducer Frame X axis Positive Forward. |
| Z Axis: | Normal to Plane of TX Transducer Frame axis Positive towards keel |

The TX Frame therefore completely defines a vessel coordinate system.

**The second coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | TDC target on IMU: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of IMU |
| Roll: | Plane of IMU |
| X Axis: | Azimuth of IMU X axis Positive Forward |
| Z Axis: | Normal to Plane of IMU axis Positive Towards keel |

IMU therefore completely defines a vessel coordinate system.

**The third coordinate system requested by NOAA is defined as follows:**

| | |
|---|---|
| Origin: | TDC target on ORU: X=0.000, Y=0.000, Z=0.000 |
| Pitch: | Plane of ORU |
| Roll: | Plane of ORU |
| X Axis: | Azimuth of ORU X axis Positive Forward |
| Z Axis: | Normal to Plane of ORU axis positive Towards keel |

ORU therefore completely defines a vessel coordinate system.

NOAA Representative requested that all survey data be presented in these coordinate systems including the draft marks.

Figure 2- Optical Reference Unit (ORU)

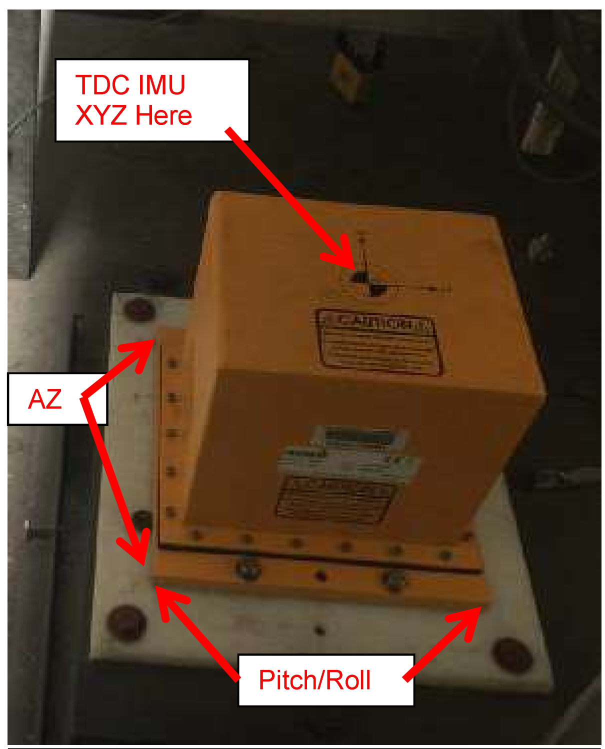

Figure 3- Inertial Measurement Unit (IMU)

## Measurement Procedure

Adhesive targets with retro reflective target face were used throughout the survey as temporary benchmarks for relocating the instrument to new stations. Kinematic (a target with a known offset) retro reflective targets such as the RT-50M swivel targets were frequently used as a temporary benchmark. The Sokkia NET 1200 total station operated through a notebook computer running Spatial Analyzer™ industrial measurement software was used to measure the targets and record observations.

## Gondola Installation

At the request of shipyard and NOAA personnel, IMTEC assisted with proper positioning of the gondola to within the azimuth, pitch and roll tolerances required by Kongsberg prior to welding.

## EM 710TX, EM 710RX and EM2040 Transducer Frames

After the transducer frames were installed, data points were surveyed at each of the bolt locations to determine overall flatness. Shim values were provided to Kongsberg to meet the flatness requirement. After shims were added and bolts final torqued, the frames were again surveyed to document final flatness. Final location (X, Y, Z), pitch, roll and azimuth of the Kongsberg transducers frames with respect to the vessel coordinate system were determined.

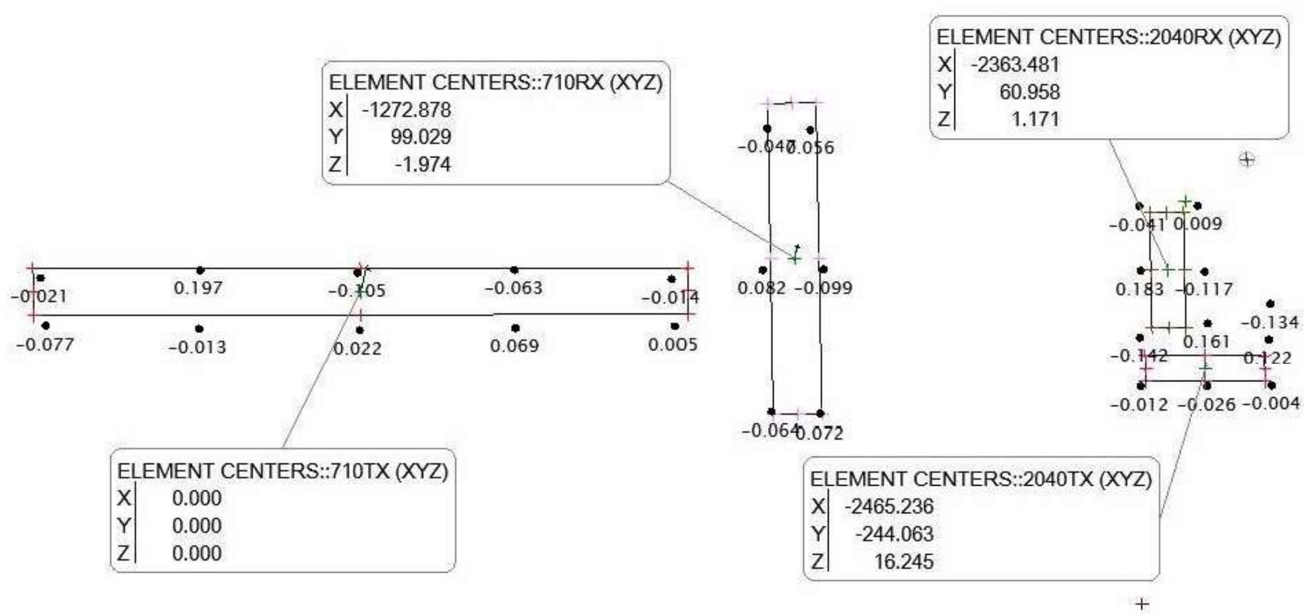


Figure 4-Flatness EM710 TX/RX and EM2040 TX/RX as Installed (mm)

## Vessel Benchmarks and Navigation Elements

Existing benchmarks and elements were surveyed as part of this effort and values for each are reported in the requested vessel orthogonal coordinate system. Additional benchmarks were added at the top of mast, at the starboard side of aft deck and at the top of the pilot house.

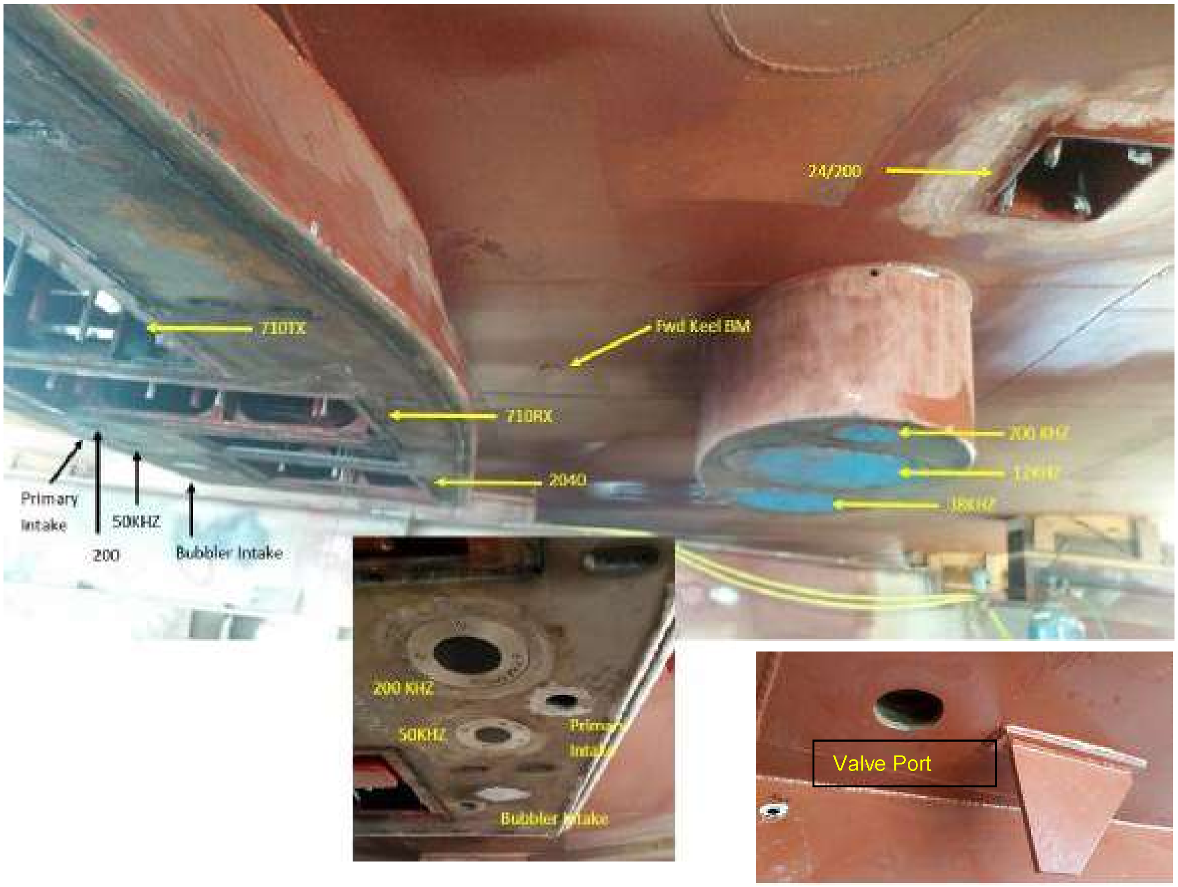


Figure 5-Elements at Bottom of Hull


Figure 6-Elements at Starboard side of Gondola

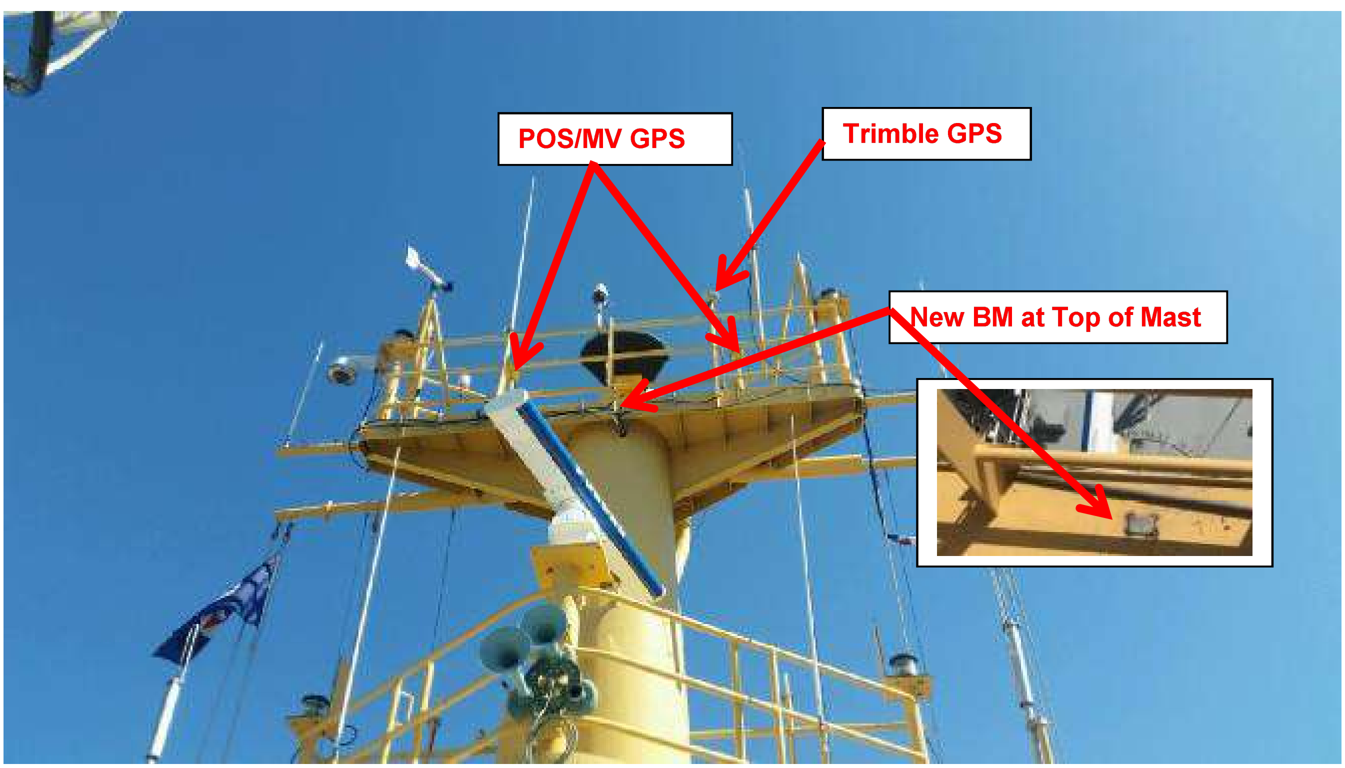


Figure 7- Mast Elements

Figure 8-GPS Antenna Elevations at bottom of Mount


Figure 9 – Scientific Store Room

BM#1


BM#2


BM#3


BM#4


BM#5


BM#6


BM#7


BM#12


BM#13


BM#14


New Aft BM


New BM Top Pilot House

Figure 10 – Bench Marks

## Measurement Precision and Uncertainty

Uncertainties are reported to be:

Point to Point, any element or target within the vessel survey to another element or feature in the survey

$X, Y, \& Z \leq 1.5$ mm

Region to Region, i.e., GPS antenna to EM710 RX/TX features:

$X \leq 2.0$ mm
$Y \leq 2.0$ mm
$Z \leq 2.0$ mm

The angular measurement precision of the NET1200 is < 1 arc second in azimuth and zenith. There can be some error introduced by targeting. Random and systematic errors can be introduced by the working environment.

The expected angular precision of the survey is analyzed to be:

Azimuth, Pitch, Roll: ≤ 00° 00' 30"

## PROJECT DATA

The required data is summarized in tabular form on the following pages. The units of measure for reporting are indicated on each table.

Table 1 reports the X, Y and Z, values for specified elements in units of meters and in the vessel coordinate system (Kongsberg System)

Table 2 reports the X, Y and Z, values for specified bench marks in units of meters and in the vessel coordinate system (Kongsberg system).

Table 3 reports the Azimuth, Pitch and Roll of specified elements in Kongsberg system.

Table 4 reports the summarized data for the draft mark survey and is presented with Feet as the unit of measure to correlate with the specific draft mark number. Draft mark elevations are reported above the best-fit keel as surveyed. The gondola projection is not reflected by any set of draft marks and projects 1.4 feet below the keel.

Appendix 1 is a copy of tables with the data presented with respect to the 1st coordinate system requested by NOAA EM710Tx Transducer Center as Origin and plane defining Pitch & Roll with azimuth clocked to X axis of transducer.

Appendix 2 is a copy of tables with the data presented with respect to the 2nd coordinate system requested by NOAA; IMU Center as Origin and plane IMU defining Pitch & Roll with azimuth clocked to X axis of IMU.

Appendix 3 is a copy of tables with the data presented with respect to the 3rd coordinate system requested by NOAA; ORU Center as Origin and ORU plane defining Pitch & Roll with azimuth clocked to X axis of ORU.

| [3]TABLE 1-ELEMENT COORDINATES SHIP SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| IMU (XYZ) | 0.000 | 0.000 | 0.000 |
| ORU (ORIGIN) | -0.843 | -0.012 | -0.132 |
| 710TX (XYZ) | -0.488 | 2.333 | 5.010 |
| 710RX (XYZ) | -1.760 | 2.434 | 5.008 |
| 2040RX (XYZ) | -2.851 | 2.397 | 5.012 |
| 2040TX (XYZ) | -2.953 | 2.092 | 5.027 |
| [1]BUBBLER ORIFICE Z | -2.989 | 2.926 | 3.917 |
| 24/200 (XYZ) | -1.264 | 0.305 | 4.439 |
| 200KHZ_1 (XYZ) | -1.911 | 0.573 | 4.887 |
| 12KHZ_1 (XYZ) | -2.431 | 0.570 | 4.887 |
| 38KHZ (XYZ) | -3.084 | 0.567 | 4.890 |
| 3.5KHZ (XYZ) | -1.873 | 6.032 | 4.398 |
| SEC INTAKE (XYZ) | -3.106 | 7.784 | 4.187 |
| SRD500 (XYZ) | -3.066 | 5.183 | 4.594 |
| VALVE PORT (XYZ) | -2.950 | 3.250 | 4.564 |
| BUBBLER INTAKE (XYZ) | -3.090 | 2.733 | 5.010 |
| 50KHZ (XYZ) | -2.611 | 2.881 | 5.012 |
| PRIMARY INTAKE (XYZ) | -2.487 | 3.013 | 5.010 |
| 200KHZ_2 (XYZ) | -2.344 | 2.882 | 5.012 |
| 12KHZ_2 (XYZ) | -1.272 | 4.555 | 4.438 |
| [2]TRIMBLE GPS | -9.040 | 1.575 | -22.214 |
| [2]POS MV PORT | -9.924 | 1.373 | -22.344 |
| [2]POS MV STBD | -9.913 | 3.583 | -22.335 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) Kongsberg System Ships Orthogonal system on TDC IMU

| TABLE 2- BENCH MARKS SHIP SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.027 | -0.567 | 0.287 |
| SCI STORE INTR #2 | -1.132 | -0.577 | 0.291 |
| SCI STORE AFT #3 | -3.294 | -0.589 | 0.289 |
| FWD KEEL #4 | -2.787 | 1.515 | 4.555 |
| AFT KEEL #5 | -16.152 | 1.51 | 4.557 |
| MAIN PASS #6 | -6.435 | 3.337 | -2.517 |
| DC PASS #7 | -16.141 | 3.287 | -2.51 |
| BOW FWD #12 | 21.026 | 2.535 | -5.183 |
| BOW MID #13 | 17.187 | 2.516 | -5.175 |
| BOW AFT#14 | 14.643 | 2.512 | -5.192 |
| PILOT HOUSE (NEW) | -7.568 | 5.304 | -12.92 |
| TOP MAST (NEW) | -9.151 | 2.942 | -20.999 |
| STBD AFT END (New) | -39.506 | 7.544 | -3.079 |

| TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| SHIP SYSTEM | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| IMU | 0.64167 | STBD | 0.07198 | BOW DOWN | 0.24375 | STBD DOWN |
| ORU | 0.04400 | PORT | 0.08500 | BOW DOWN | 0.07779 | STBD DOWN |
| EM710 TX | 0.05539 | PORT | 0.01315 | BOW UP | 0.00927 | STBD UP |
| EM710RX | 0.21797 | STBD | 0.09935 | BOW UP | 0.06457 | STBD DOWN |
| EM2040TX | 0.1466 | STBD | 0.19035 | BOW UP | 0.08625 | STBD UP |
| EM2040RX | 0.13963 | STBD | 0.20005 | BOW UP | 0.17817 | STBD UP |

| TABLE 4 - DRAFT MARKS (elev above keel, feet) | | | | | | | |
|---|---|---|---|---|---|---|---|
| PORT | | | | STARBOARD | | | |
| DRAFT MARK | ELEVATION AS SURVEYED | | | DRAFT MARK | ELEVATION AS SURVEYED | | |
| | FWD | MID | AFT | | FWD | MID | AFT |
| 12 | - | - | - | 12 | - | 11.9 | - |
| 13 | 12.9 | - | - | 13 | 12.9 | - | - |
| 14 | 13.9 | 14.0 | - | 14 | 13.9 | 13.9 | - |
| 15 | 15.0 | 15.0 | 15.1 | 15 | 15.0 | 14.9 | 15.1 |
| 16 | 16.0 | 16.0 | 16.1 | 16 | 16.0 | 15.9 | 16.0 |
| 17 | 16.9 | 17.0 | 17.1 | 17 | 16.9 | 16.9 | 17.1 |

# Certificate of Calibration

Item No. / Model: NET 1200

Manufacturer: SOKKIA

Serial No.: 110554 Certificate Number: 60997

This certifies that the above instrument has been inspected and calibrated by the Sokkia Corporation Service Department. This inspection was performed using the procedures set forth in the NET SERIES INSTRUMENT CALIBRATION AND CERTIFICATION MANUAL (August 18, 2005 Rev. 8). At the time of completion of this service, Sokkia Corporation certifies that the above stated instrument meets or exceeds all factory specifications and tolerances for instrument parameters and performance of this instrument model. The certification is effective for a 12 month period from the calibration date shown below.

All distance measurement parameters were tested and adjusted using factory calibration jigs and with the 10 Meter Calibration Rail whose accuracy is traceable to the National Institute of Standards and Technology (N.I.S.T) via Multual Recognition Agreement. All angle measurement parameters were tested with a NIST traceable optical collimation system, using accepted collimation and adjustment procedures.

The quality system addresses and conforms to ANSI/NCSL Z540-1-1994 and ISO/IEC 17025-1999 (and, as a result ISO 9001-1994 or ISO 9002-1994)

This certificate shall not be reproduced except in full, without the written approval of Sokkia Corporation

Customer Name: IMTEC GROUP, Ltd

Customer Address: 19004 E. RINGO CIR.

Customer City/State/Zip: INDEPENDENCE, MO 64057

See individual sets of data for temperature and pressure

Date Calibrated: 11/17/2015 Date Recalibration Due: 11/17/2016

Signed: Ale Erkin Date: 11/17/2015

| Yes | No | |
|---|---|---|
| | X | Is this a new instrument? |

Answer the following questions only if the above answer is "No".

| Yes | No | |
|---|---|---|
| | X | Is this the first NIST calibration we have performed on this instrument? |
| X | | Were the calibration seals intact when the instrument was received? |
| | X | Were the initial collimation inspection results within tolerance? |
| | X | Were the initial EDM inspection results within tolerance? |
| | X | Was the instrument damaged/defective and unable to have an initial inspection? |
| | X | Corrective action recommended? |

* See page 2 for a list of primary standards

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## Appendix 1 – NOAA Requested System wrt 710TX

| (3) A1 TABLE 1-ELEMENT COORDINATES 710TX SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| IMU (XYZ) | 0.491 | -2.332 | -5.010 |
| ORU (ORIGIN) | -0.351 | -2.345 | -5.143 |
| 710TX (XYZ) | 0.000 | 0.000 | 0.000 |
| 710RX (XYZ) | -1.273 | 0.099 | -0.002 |
| 2040RX (XYZ) | -2.363 | 0.061 | 0.001 |
| 2040TX (XYZ) | -2.465 | -0.244 | 0.016 |
| (1)BUBBLER ORIFICE Z | -2.501 | 0.590 | -1.094 |
| 24/200 (XYZ) | -0.774 | -2.029 | -0.571 |
| 200KHZ_1 (XYZ) | -1.421 | -1.762 | -0.124 |
| 12KHZ_1 (XYZ) | -1.942 | -1.765 | -0.123 |
| 38KHZ (XYZ) | -2.594 | -1.769 | -0.121 |
| 3.5KHZ (XYZ) | -1.389 | 3.698 | -0.612 |
| SEC INTAKE (XYZ) | -2.623 | 5.448 | -0.823 |
| SRD500 (XYZ) | -2.581 | 2.847 | -0.417 |
| VALVE PORT (XYZ) | -2.463 | 0.914 | -0.447 |
| BUBBLER INTAKE (XYZ) | -2.603 | 0.397 | -0.001 |
| 50KHZ (XYZ) | -2.124 | 0.545 | 0.002 |
| PRIMARY INTAKE (XYZ) | -2.000 | 0.678 | 0.000 |
| 200KHZ_2 (XYZ) | -1.857 | 0.546 | 0.002 |
| 12KHZ_2 (XYZ) | -0.786 | 2.221 | -0.572 |
| (2)TRIMBLE GPS | -8.545 | -0.762 | -27.226 |
| (2)POS MV PORT | -9.429 | -0.965 | -27.357 |
| (2)POS MV STBD | -9.420 | 1.245 | -27.347 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 1 Orthogonal system on 710TX

| **A1 TABLE 2- BENCH MARKS 710TX SYSTEM (m)** | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.519 | -2.898 | -4.723 |
| SCI STORE INTR #2 | -0.64 | -2.911 | -4.72 |
| SCI STORE AFT #3 | -2.803 | -2.924 | -4.722 |
| FWD KEEL #4 | -2.299 | -0.82 | -0.456 |
| AFT KEEL #5 | -15.663 | -0.838 | -0.457 |
| MAIN PASS #6 | -5.946 | 1 | -7.528 |
| DC PASS #7 | -15.652 | 0.94 | -7.523 |
| BOW FWD #12 | 21.516 | 0.224 | -10.189 |
| BOW MID #13 | 17.677 | 0.201 | -10.181 |
| BOW AFT#14 | 15.133 | 0.195 | -10.198 |
| PILOT HOUSE (NEW) | -7.079 | 2.967 | -17.931 |
| TOP MAST (NEW) | -8.658 | 0.604 | -26.011 |
| STBD AFT END (New) | -39.022 | 5.174 | -8.097 |

| A1 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS 710 TX SYSTEM (decimal dgrees) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.69705 | STBD | 0.08490 | BOW DOWN | 0.25310 | STBD DOWN |
| ORU | 0.01138 | STBD | 0.09813 | BOW DOWN | 0.08710 | STBD DOWN |
| EM710 TX | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| EM710RX | 0.27337 | STBD | 0.08627 | BOW UP | 0.07377 | STBD DOWN |
| EM2040TX | 0.20202 | STBD | 0.17713 | BOW UP | 0.07714 | STBD UP |
| EM2040RX | 0.19498 | STBD | 0.18675 | BOW UP | 0.16907 | STBD UP |

## Appendix 2 – NOAA Requested System wrt IMU

| (3) A2- TABLE 1-ELEMENT COORDINATES IMU SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| (4) IMU (XYZ) | 0 | 0 | 0 |
| ORU (ORIGIN) | -0.843 | -0.003 | -0.131 |
| 710TX (XYZ) | -0.455 | 2.36 | 5.001 |
| 710RX (XYZ) | -1.727 | 2.474 | 5 |
| 2040RX (XYZ) | -2.818 | 2.45 | 5.005 |
| 2040TX (XYZ) | -2.923 | 2.146 | 5.022 |
| (1) BUBBLER ORIFICE Z | -2.951 | 2.975 | 3.908 |
| 24/200 (XYZ) | -1.255 | 0.338 | 4.44 |
| 200KHZ_1 (XYZ) | -1.898 | 0.615 | 4.887 |
| 12KHZ_1 (XYZ) | -2.418 | 0.618 | 4.888 |
| 38KHZ (XYZ) | -3.071 | 0.623 | 4.892 |
| 3.5KHZ (XYZ) | -1.8 | 6.071 | 4.375 |
| SEC INTAKE (XYZ) | -3.013 | 7.836 | 4.157 |
| SRD500 (XYZ) | -3.002 | 5.237 | 4.575 |
| VALVE PORT (XYZ) | -2.908 | 3.302 | 4.554 |
| BUBBLER INTAKE (XYZ) | -3.053 | 2.789 | 5.002 |
| 50KHZ (XYZ) | -2.572 | 2.931 | 5.003 |
| PRIMARY INTAKE (XYZ) | -2.447 | 3.062 | 5 |
| 200KHZ_2 (XYZ) | -2.305 | 2.929 | 5.003 |
| 12KHZ_2 (XYZ) | -1.215 | 4.588 | 4.42 |
| (2) TRIMBLE GPS | -9.051 | 1.582 | -22.209 |
| (2) POS MV PORT | -9.937 | 1.389 | -22.338 |
| (2) POS MV STBD | -9.901 | 3.599 | -22.337 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 2 Orthogonal system on IMU
(4)TDC IMU is 4.6 meters above Keel

| A2 TABLE 2- BENCH MARKS IMU SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.021 | -0.577 | 0.289 |
| SCI STORE INTR #2 | -1.138 | -0.563 | 0.294 |
| SCI STORE AFT #3 | -3.300 | -0.550 | 0.296 |
| FWD KEEL #4 | -2.764 | 1.566 | 4.552 |
| AFT KEEL #5 | -16.128 | 1.710 | 4.571 |
| MAIN PASS #6 | -6.400 | 3.399 | -2.523 |
| DC PASS #7 | -16.106 | 3.457 | -2.503 |
| BOW FWD #12 | 21.046 | 2.277 | -5.221 |
| BOW MID #13 | 17.207 | 2.301 | -5.207 |
| BOW AFT#14 | 14.664 | 2.326 | -5.221 |
| PILOT HOUSE (NEW) | -7.525 | 5.334 | -12.932 |
| TOP MAST (NEW) | -9.145 | 2.955 | -21.000 |
| STBD AFT END (New) | -39.423 | 7.973 | -3.061 |

| A2 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees IMU System) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| ORU | 0.68556 | PORT | 0.01122 | BOW DOWN | 0.16615 | STBD UP |
| EM710 TX | 0.69738 | PORT | 0.08796 | BOW UP | 0.25206 | STBD UP |
| EM710RX | 0.42371 | PORT | 0.17333 | BOW UP | 0.17725 | STBD UP |
| EM2040TX | 0.49611 | PORT | 0.26602 | BOW UP | 0.32704 | STBD UP |
| EM2040RX | 0.50177 | PORT | 0.27675 | BOW UP | 0.41885 | STBD UP |

## Appendix 3 – NOAA Requested Coordinates wrt ORU

| (3) A3 TABLE 1-ELEMENT COORDINATES ORU SYSTEM (m) | | | |
|---|---|---|---|
| **ELEMENT** | **X** | **Y** | **Z** |
| (4)IMU (XYZ) | 0.843 | 0.013 | 0.131 |
| ORU (ORIGIN) | 0.000 | 0.000 | 0.000 |
| 710TX (XYZ) | 0.361 | 2.353 | 5.139 |
| 710RX (XYZ) | -0.912 | 2.452 | 5.139 |
| 2040RX (XYZ) | -2.003 | 2.414 | 5.144 |
| 2040TX (XYZ) | -2.105 | 2.109 | 5.160 |
| (1)BUBBLER ORIFICE Z | -2.142 | 2.941 | 4.048 |
| 24/200 (XYZ) | -0.415 | 0.322 | 4.572 |
| 200KHZ_1 (XYZ) | -1.061 | 0.591 | 5.020 |
| 12KHZ_1 (XYZ) | -1.582 | 0.587 | 5.021 |
| 38KHZ (XYZ) | -2.234 | 0.584 | 5.025 |
| 3.5KHZ (XYZ) | -1.029 | 6.049 | 4.524 |
| SEC INTAKE (XYZ) | -2.263 | 7.800 | 4.312 |
| SRD500 (XYZ) | -2.221 | 5.200 | 4.722 |
| VALVE PORT (XYZ) | -2.103 | 3.266 | 4.695 |
| BUBBLER INTAKE (XYZ) | -2.242 | 2.750 | 5.142 |
| 50KHZ (XYZ) | -1.763 | 2.898 | 5.143 |
| PRIMARY INTAKE (XYZ) | -1.639 | 3.031 | 5.141 |
| 200KHZ_2 (XYZ) | -1.496 | 2.899 | 5.143 |
| 12KHZ_2 (XYZ) | -0.426 | 4.573 | 4.565 |
| (2)TRIMBLE GPS | -8.231 | 1.550 | -22.071 |
| (2)POS MV PORT | -9.115 | 1.348 | -22.201 |
| (2)POS MV STBD | -9.106 | 3.558 | -22.194 |

(1) Bubbler Orfice Z (X and Y approx)
(2) Z at Base, see Figure 8
(3) NOAA Requested System 3 Orthogonal system on ORU
(4)TDC ORU is 4.7 meters above Keel

| A3 TABLE 2- BENCH MARKS ORU SYSTEM (m) | | | |
|---|---|---|---|
| BENCH MARK | X | Y | Z |
| SCI STORE FWD #1 | 1.871 | -0.553 | 0.418 |
| SCI STORE INTR #2 | -0.288 | -0.565 | 0.424 |
| SCI STORE AFT #3 | -2.451 | -0.578 | 0.426 |
| FWD KEEL #4 | -1.939 | 1.532 | 4.688 |
| AFT KEEL #5 | -15.304 | 1.517 | 4.710 |
| MAIN PASS #6 | -5.598 | 3.342 | -2.381 |
| DC PASS #7 | -15.304 | 3.284 | -2.359 |
| BOW FWD #12 | 21.859 | 2.556 | -5.087 |
| BOW MID #13 | 18.020 | 2.535 | -5.072 |
| BOW AFT#14 | 15.476 | 2.529 | -5.086 |
| PILOT HOUSE (NEW) | -6.749 | 5.294 | -12.784 |
| TOP MAST (NEW) | -8.342 | 2.919 | -20.858 |
| STBD AFT END (New) | -38.674 | 7.522 | -2.900 |

| A3 -TABLE 3 - HEADING, PITCH. ROLL OF ELEMENTS (decimal dgrees ORU System) | | | | | | |
|---|---|---|---|---|---|---|
| ELEMENT | HEADING | | PITCH | | ROLL | |
| | VALUE | DIRECTION | VALUE | DIRECTION | VALUE | DIRECTION |
| IMU | 0.68529 | STBD | 0.01321 | BOW UP | 0.16601 | STBD DOWN |
| ORU | 0.00000 | - | 0.00000 | - | 0.00000 | - |
| EM710 TX | 0.01276 | PORT | 0.09815 | BOW UP | 0.08708 | STBD UP |
| EM710RX | 0.26191 | STBD | 0.18441 | BOW UP | 0.01330 | STBD UP |
| EM2040TX | 0.18694 | STBD | 0.27532 | BOW UP | 0.16419 | STBD UP |
| EM2040RX | 0.18391 | STBD | 0.28496 | BOW UP | 0.25613 | STBD UP |
| 24/200 kHz | - | - | 0.47762 | BOW UP | 0.02678 | STBD DOWN |
| 12kHz-2 | - | - | 0.36558 | BOW UP | 0.23158 | STBD UP |
| 12kHz-1 | - | - | 0.23913 | BOW UP | 0.09000 | STBD UP |
| 200kHz-1 | - | - | 0.13427 | BOW UP | 0.46860 | STBD UP |
| 200kHz-2 | - | - | 0.08863 | BOW UP | 0.32335 | STBD UP |
| 38kHz | - | - | 0.32417 | BOW UP | 0.01594 | STBD DOWN |
| 50kHz | - | - | 0.34673 | BOW UP | 0.43530 | STBD UP |
| SRD500 | - | - | 0.54483 | BOW UP | 0.71415 | STBD DOWN |
| 3.5 kHz | - | - | 0.17175 | BOW UP | 0.04851 | STBD DOWN |
| ADCP(1) | - | - | - | - | - | - |

(1) ADCP not installed at time of survey

## Appendix 6.2: 2903 Echosounder Confidence Check

# 2903 Echosounder Acceptance Report

NOAA HSL 2903 with new Kongsberg EM2040 MBES systems had completed a sonar acceptance test and been approved for use by NOAA's Hydrographic Systems and Technology Branch at the time of this report, but an acceptance report had not been completed for the equipment.

This report will be updated upon completion of sonar acceptance and confidence checks.

Date valid: 2018-06-05

## Appendix 6.3: 2904 Echosounder Confidence Check

# 2904 Echosounder Acceptance Report

NOAA HSL 2904 with new Kongsberg EM2040 MBES systems had not completed sonar acceptance testing or confidence checks at the time of submission of this report.

HSL 2904 has not been used for any survey operations since installation of the new sonar systems.

This report will be updated upon completion of sonar acceptance and confidence checks.

Date valid: 2018-06-05

# Appendix 7:

# HVF reports

Updated: 6/5/2018

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<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
  <VesselShape>
    <PlanCoordinates/>
    <ProfileCoordinates/>
    <RP Length="0.000000" Width="0.000000" Height="0.000000"/>
  </VesselShape>
  <NavSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
    </TimeStamp>
  </NavSensor>
  <GyroSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
    </TimeStamp>
  </GyroSensor>
  <HeaveSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000" Heave="0.000000"/>
    </TimeStamp>
  </HeaveSensor>
  <PitchSensor>
    <TimeStamp value="2018-142 00:00:00">
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      <ApplyFlag value="No"/>
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    </TimeStamp>
  </PitchSensor>
  <RollSensor>
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      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
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    </TimeStamp>
  </RollSensor>
  <DraftSensor>
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      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <ApplyFlag value="Yes"/>
      <DraftEntries>
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        <Entry Speed="0.971922" Draft="0.010000"/>
        <Entry Speed="1.943844" Draft="0.020000"/>
        <Entry Speed="2.915767" Draft="0.030000"/>
        <Entry Speed="3.887689" Draft="0.040000"/>
        <Entry Speed="4.859611" Draft="0.050000"/>
        <Entry Speed="5.831533" Draft="0.060000"/>
        <Entry Speed="6.803456" Draft="0.060000"/>
        <Entry Speed="7.775378" Draft="0.060000"/>
        <Entry Speed="8.747300" Draft="0.050000"/>
        <Entry Speed="9.719222" Draft="0.040000"/>
        <Entry Speed="10.691145" Draft="0.020000"/>
        <Entry Speed="11.663067" Draft="-0.010000"/>
        <Entry Speed="12.634989" Draft="-0.050000"/>
        <Entry Speed="13.606911" Draft="-0.090000"/>
      </DraftEntries>
    </TimeStamp>
```

```
  </DraftSensor>
  <WaterlineHeight>
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      <Comment value="(null)"/>
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    </TimeStamp>
  </WaterlineHeight>
  <SVPSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Comment value="SVP1 = TX; TX is ref, so all values 0"/>
      <Latency value="0.000000"/>
      <DualHead value="Yes"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000" X2="-0.305000" Y2="-0.100000" Z2=
      "-0.016000"/>
      <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000" Pitch2="0.000000" Roll2=
      "0.000000" Azimuth2="0.000000"/>
    </TimeStamp>
  </SVPSensor>
  <DepthSensor>
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      <TransducerEntries>
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          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
        <Transducer Number="2" StartBeam="1001" Model="Unknown">
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          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
  </DepthSensor>
  <TPEConfiguration>
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        Z2="-0.520000"/>
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        <Navigation Latency="0.000000"/>
      </Offsets>
      <StandardDeviation>
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        Pitch="0.005000" PitchStablized="0.000000"/>
        <Position Navigation="0.100000"/>
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        Pitch="0.003000" Roll="0.003000"/>
        <SoundVelocity Measured="0.000000" Surface="0.000000"/>
        <Tide Measured="0.000000" Zoning="0.000000"/>
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        <MRUAlignment Gyro="0.000000" Pitch="0.000000" Roll="0.000000"/>
        <Vessel Speed="0.100000" Loading="0.030000" Draft="0.030000" DeltaDraft="0.020000">
          <StDevComment value="(null)"/>
        </Vessel>
      </StandardDeviation>
    </TimeStamp>
```

</TPEConfiguration>
</HIPSVesselConfig>

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2903_EM2040_2018 | | | | | |
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | | | |
| POS Ref to IMU | -0.148 | -0.208 | -0.447 | | | |
| POS Ref to Primary GPS | -0.896 | -0.922 | -4.185 | | | |
| POS IMU to Ref Frame | -0.2 | 0.25 | 1.54 | | | |
| | | | | | | |
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | Roll | Pitch | Yaw |
| Kongs TX Offset | 0 | 0 | 0 | 0 | 0 | 0 |
| Kongs RX Offset | -0.1 | -0.305 | -0.016 | 0 | 0 | 0 |
| Kongs Waterline | 0 | 0 | -0.694 | | | |
| | | | | | | |
| | X (+STBD) | Y (+FWD) | Z (+DOWN) | Pitch | Roll | Yaw |
| Caris Trans 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris Trans 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 2 | -0.305 | -0.1 | -0.016 | 0 | 0 | 0 |
| Caris Heave | 0 | 0 | 0 | | | |
| Caris Waterline | 0 | 0 | -0.694 | | | |
| | | | | | | |
| | Heave | Pitch | Roll | Draft | Waterline | |
| Caris Apply Flags | No | No | No | Yes | No | |

Offset Checks:

| | |
|---|---|
| Caris HVF SVP2 and Kongs RX are equal | Yes |
| Caris HVF SVP1 and .all Kongs TX are equal | No |
| Caris HVF Heave is opposite of .all Kongsberg TX Offset with HVF Apply = No | Yes |
| Caris HVF Waterline has a value | Yes |
| POS Primary GPS Antenna Value above IMU | Yes |
| RP at IMU | No |

```xml
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<HIPSVesselConfig Version="2.0">
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    <ProfileCoordinates/>
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  <NavSensor>
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      <Ellipse value="WG84"/>
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      <SerialNumber value="(null)"/>
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  </GyroSensor>
  <TowedSensor>
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      <Manufacturer value=""/>
      <Model value=""/>
      <SerialNumber value=""/>
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```xml
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  </VesselShape>
  <NavSensor>
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      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
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      <Comment value="(null)"/>
      <Manufacturer value="Applanix"/>
      <Model value="POS M/V V4"/>
      <SerialNumber value="(null)"/>
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      <Model value=""/>
      <SerialNumber value=""/>
      <Offsets X="0.564000" Y="0.654000" Z="0.310000" Layback="0.000000"/>
    </TimeStamp>
  </TowedSensor>
</HIPSVesselConfig>
```

```xml
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    <PlanCoordinates/>
    <ProfileCoordinates/>
    <RP Length="0.000000" Width="0.000000" Height="0.000000"/>
  </VesselShape>
  <NavSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
    </TimeStamp>
  </NavSensor>
  <GyroSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
    </TimeStamp>
  </GyroSensor>
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      <Offsets X="0.000000" Y="0.000000" Z="0.000000" Heave="0.000000"/>
    </TimeStamp>
  </HeaveSensor>
  <PitchSensor>
    <TimeStamp value="2018-142 00:00:00">
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      <ApplyFlag value="No"/>
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    </TimeStamp>
  </PitchSensor>
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  </RollSensor>
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        <Entry Speed="1.943844" Draft="0.020000"/>
        <Entry Speed="2.915767" Draft="0.030000"/>
        <Entry Speed="3.887689" Draft="0.040000"/>
        <Entry Speed="4.859611" Draft="0.050000"/>
        <Entry Speed="5.831533" Draft="0.060000"/>
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        <Entry Speed="7.775378" Draft="0.060000"/>
        <Entry Speed="8.747300" Draft="0.050000"/>
        <Entry Speed="9.719222" Draft="0.040000"/>
        <Entry Speed="10.691145" Draft="0.020000"/>
        <Entry Speed="11.663067" Draft="-0.010000"/>
        <Entry Speed="12.634989" Draft="-0.050000"/>
        <Entry Speed="13.606911" Draft="-0.090000"/>
      </DraftEntries>
    </TimeStamp>
```

```
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      <StdDev Waterline="0.000000"/>
    </TimeStamp>
  </WaterlineHeight>
  <SVPSensor>
    <TimeStamp value="2018-142 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <DualHead value="Yes"/>
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      Z2="-0.016000"/>
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      Roll2="0.070000" Azimuth2="0.000000"/>
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      <DualHead value="Yes"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000" X2="-0.305000" Y2="-0.100000"
      Z2="-0.016000"/>
      <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000" Pitch2="0.000000"
      Roll2="0.000000" Azimuth2="0.000000"/>
    </TimeStamp>
  </SVPSensor>
  <DepthSensor>
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      <TransducerEntries>
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        </Transducer>
        <Transducer Number="2" StartBeam="1001" Model="Unknown">
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          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
  </DepthSensor>
  <TPEConfiguration>
    <TimeStamp value="2018-142 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <Offsets>
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        Z2="0.522000"/>
        <NavigationToTransducer X="-0.923000" Y="-0.889000" Z="-4.193000" X2="-0.619000"
        Y2="-0.789000" Z2="-4.176000"/>
        <Transducer Roll="0.000000" Roll2="0.000000"/>
        <Navigation Latency="0.000000"/>
      </Offsets>
      <StandardDeviation>
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        Pitch="0.005000" PitchStablized="0.000000"/>
        <Position Navigation="0.100000"/>
        <Timing Transducer="0.003000" Navigation="0.003000" Gyro="0.003000" Heave="0.003000"
        Pitch="0.003000" Roll="0.003000"/>
```

```
        &lt;SoundVelocity Measured="0.000000" Surface="0.000000"/&gt;
        &lt;Tide Measured="0.000000" Zoning="0.000000"/&gt;
        &lt;Offsets X="0.020000" Y="0.020000" Z="0.020000"/&gt;
        &lt;MRUAlignment Gyro="0.000000" Pitch="0.000000" Roll="0.000000"/&gt;
        &lt;Vessel Speed="0.100000" Loading="0.030000" Draft="0.030000" DeltaDraft="0.020000"&gt;
          &lt;StDevComment value="(null)"/&gt;
        &lt;/Vessel&gt;
      &lt;/StandardDeviation&gt;
    &lt;/TimeStamp&gt;
  &lt;/TPEConfiguration&gt;
&lt;/HIPSVesselConfig&gt;
```

| | 2904_EM2040_2018 | | | | | |
|---|---|---|---|---|---|---|
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | | | |
| POS Ref to IMU | -0.152 | -0.195 | -0.449 | | | |
| POS Ref to Primary GPS | -0.889 | -0.923 | -4.193 | | | |
| POS IMU to Ref Frame | -0.256 | -0.118 | -0.076 | | | |
| | | | | | | |
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | Roll | Pitch | Yaw |
| Kongs TX Offset | 0 | 0 | 0 | 0 | 0 | 0 |
| Kongs RX Offset | -0.1 | -0.305 | -0.016 | 0 | 0 | 0 |
| Kongs Waterline | 0 | 0 | -0.694 | | | |
| | | | | | | |
| | X (+STBD) | Y (+FWD) | Z (+DOWN) | Pitch | Roll | Yaw |
| Caris Trans 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris Trans 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 2 | -0.305 | -0.1 | -0.016 | 0 | 0 | 0 |
| Caris Heave | 0 | 0 | 0 | | | |
| Caris Waterline | 0 | 0 | -0.694 | | | |
| | | | | | | |
| | Heave | Pitch | Roll | Draft | Waterline | |
| Caris Apply Flags | No | No | No | Yes | No | |

Offset Checks:

| | |
|---|---|
| Caris HVF SVP2 and Kongs RX are equal | Yes |
| Caris HVF SVP1 and .all Kongs TX are equal | No |
| Caris HVF Heave is opposite of .all Kongsberg TX Offset with HVF Apply = No | Yes |
| Caris HVF Waterline has a value | Yes |
| POS Primary GPS Antenna Value above IMU | Yes |
| RP at IMU | No |

```xml
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
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    <ProfileCoordinates/>
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  </VesselShape>
  <NavSensor>
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      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
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      <Manufacturer value="Applanix"/>
      <Model value="POS M/V V5"/>
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      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
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  <TowedSensor>
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      <Comment value=""/>
      <Latency value="0.000000"/>
      <Manufacturer value=""/>
      <Model value=""/>
      <SerialNumber value=""/>
      <Offsets X="0.574000" Y="0.659000" Z="0.306000" Layback="0.000000"/>
    </TimeStamp>
  </TowedSensor>
</HIPSVesselConfig>
```

```xml
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
  <VesselShape>
    <PlanCoordinates/>
    <ProfileCoordinates/>
    <RP Length="0.000000" Width="0.000000" Height="0.000000"/>
  </VesselShape>
  <NavSensor>
    <TimeStamp value="2018-098 00:00:00">
      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="Applanix"/>
      <Model value="POS M/V V4"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
  </NavSensor>
  <GyroSensor>
    <TimeStamp value="2018-098 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Comment value="(null)"/>
      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
  </GyroSensor>
  <TowedSensor>
    <TimeStamp value="2018-098 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <Manufacturer value=""/>
      <Model value=""/>
      <SerialNumber value=""/>
      <Offsets X="0.574000" Y="0.659000" Z="0.306000" Layback="0.000000"/>
    </TimeStamp>
  </TowedSensor>
</HIPSVesselConfig>
```

```xml
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
  <VesselShape>
    <PlanCoordinates/>
    <ProfileCoordinates/>
    <RP Length="0.000000" Width="0.000000" Height="0.000000"/>
  </VesselShape>
  <NavSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
    </TimeStamp>
  </NavSensor>
  <GyroSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
    </TimeStamp>
  </GyroSensor>
  <HeaveSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000" Heave="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2017-214 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <Manufacturer value=""/>
      <Model value=""/>
      <SerialNumber value=""/>
      <ApplyFlag value="No"/>
      <Offsets X="-2.360000" Y="0.455000" Z="-5.001000" Heave="0.000000"/>
    </TimeStamp>
  </HeaveSensor>
  <PitchSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Pitch="0.000000"/>
    </TimeStamp>
  </PitchSensor>
  <RollSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Roll="0.000000"/>
    </TimeStamp>
  </RollSensor>
  <DraftSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="Yes"/>
      <DraftEntries>
        <Entry Speed="0.000000" Draft="0.000000"/>
        <Entry Speed="0.971922" Draft="-0.012000"/>
        <Entry Speed="1.943844" Draft="-0.012000"/>
        <Entry Speed="2.915767" Draft="-0.004000"/>
        <Entry Speed="3.887689" Draft="0.018000"/>
        <Entry Speed="4.859611" Draft="0.040000"/>
        <Entry Speed="5.831533" Draft="0.068000"/>
        <Entry Speed="6.803456" Draft="0.104000"/>
        <Entry Speed="7.775378" Draft="0.140000"/>
```

```
        <Entry Speed="8.747300" Draft="0.186000"/>
        <Entry Speed="9.719222" Draft="0.232000"/>
        <Entry Speed="10.691145" Draft="0.284000"/>
        <Entry Speed="11.663067" Draft="0.350000"/>
      </DraftEntries>
    </TimeStamp>
  </DraftSensor>
  <WaterlineHeight>
    <TimeStamp value="2016-278 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.371000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-121 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.266000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-128 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.381000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-142 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <WaterLine value="0.472000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
  </WaterlineHeight>
  <SVPSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <DualHead value="Yes"/>
      <Offsets X="2.360000" Y="-0.455000" Z="5.001000" X2="2.474000" Y2="-1.727000" Z2=
      "5.000000"/>
      <MountAngle Pitch="0.088000" Roll="-0.252000" Azimuth="359.302000" Pitch2="0.173000" Roll2
      ="-0.177000" Azimuth2="359.576000"/>
    </TimeStamp>
  </SVPSensor>
  <DepthSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="em710_0.5x1">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
        <Transducer Number="2" StartBeam="1002" Model="em2040_300N">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
  </DepthSensor>
```

```
  <TPEConfiguration>
    <TimeStamp value="2015-001 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <Offsets>
        <MRUtoTransducer X="2.360000" Y="-0.455000" Z="5.001000" X2="2.474000" Y2="-1.727000" Z2
        ="5.000000"/>
        <NavigationToTransducer X="0.971000" Y="9.482000" Z="27.339000" X2="1.085000" Y2=
        "8.210000" Z2="27.338000"/>
        <Transducer Roll="0.000000" Roll2="0.000000"/>
        <Navigation Latency="0.000000"/>
      </Offsets>
      <StandardDeviation>
        <Motion Gyro="0.015000" HeavePercAmplitude="2.000000" Heave="0.020000" Roll="0.003000"
        Pitch="0.003000" PitchStablized="0.000000"/>
        <Position Navigation="0.100000"/>
        <Timing Transducer="0.001000" Navigation="0.001000" Gyro="0.001000" Heave="0.001000"
        Pitch="0.001000" Roll="0.001000"/>
        <SoundVelocity Measured="0.000000" Surface="0.000000"/>
        <Tide Measured="0.000000" Zoning="0.000000"/>
        <Offsets X="0.002000" Y="0.002000" Z="0.002000"/>
        <MRUAlignment Gyro="0.030000" Pitch="0.010000" Roll="0.010000"/>
        <Vessel Speed="0.030000" Loading="0.060000" Draft="0.035000" DeltaDraft="0.050000">
          <StDevComment value="(null)"/>
        </Vessel>
      </StandardDeviation>
    </TimeStamp>
  </TPEConfiguration>
</HIPSVesselConfig>
```

| | S222_EM710_2018 | | | | | |
|---|---|---|---|---|---|---|
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | | | |
| POS Ref to IMU | 0.005 | -0.006 | 0.089 | | | |
| POS Ref to Primary GPS | -9.937 | 1.389 | -22.421 | | | |
| POS IMU to Ref Frame | 0 | 0 | 0 | | | |
| | | | | | | |
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | Roll | Pitch | Yaw |
| Kongs TX Offset | -0.455 | 2.36 | 5.001 | -0.252 | 0.088 | 359.302 |
| Kongs RX Offset | -1.727 | 2.474 | 5 | -0.177 | 0.173 | 359.576 |
| Kongs Waterline | 0 | 0 | 0.472 | | | |
| | | | | | | |
| | X (+STBD) | Y (+FWD) | Z (+DOWN) | Pitch | Roll | Yaw |
| Caris Trans 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 1 | 2.36 | -0.455 | 5.001 | 0.088 | -0.252 | 359.302 |
| Caris Trans 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Caris SVP 2 | 2.474 | -1.727 | 5 | 0.173 | -0.177 | 359.576 |
| Caris Heave | -2.36 | 0.455 | -5.001 | | | |
| Caris Waterline | 0 | 0 | 0.307 | | | |
| | | | | | | |
| | Heave | Pitch | Roll | Draft | Waterline | |
| Caris Apply Flags | No | No | No | Yes | No | |

| | |
|---|---|
| Offset Checks: | |
| Caris HVF SVP2 and Kongs RX are equal | Yes |
| Caris HVF SVP1 and .all Kongs TX are equal | No |
| Caris HVF Heave is opposite of .all Kongsberg TX Offset with HVF Apply = No | Yes |
| Caris HVF Waterline has a value | Yes |
| POS Primary GPS Antenna Value above IMU | Yes |
| RP at IMU | Yes |

```xml
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
  <VesselShape>
    <PlanCoordinates/>
    <ProfileCoordinates/>
    <RP Length="0.000000" Width="0.000000" Height="0.000000"/>
  </VesselShape>
  <NavSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
    </TimeStamp>
  </NavSensor>
  <GyroSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
    </TimeStamp>
  </GyroSensor>
  <HeaveSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets X="-2.146000" Y="2.923000" Z="-5.022000" Heave="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
  </HeaveSensor>
  <PitchSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Pitch="0.000000"/>
    </TimeStamp>
  </PitchSensor>
  <RollSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Roll="0.000000"/>
    </TimeStamp>
  </RollSensor>
  <DraftSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="Yes"/>
      <DraftEntries>
        <Entry Speed="0.000000" Draft="0.000000"/>
        <Entry Speed="0.971922" Draft="-0.020000"/>
        <Entry Speed="1.943844" Draft="-0.030000"/>
        <Entry Speed="2.915767" Draft="-0.020000"/>
        <Entry Speed="3.887689" Draft="-0.010000"/>
        <Entry Speed="4.859611" Draft="0.030000"/>
        <Entry Speed="5.831533" Draft="0.060000"/>
        <Entry Speed="6.803456" Draft="0.100000"/>
        <Entry Speed="7.775378" Draft="0.130000"/>
        <Entry Speed="8.747300" Draft="0.180000"/>
        <Entry Speed="9.719222" Draft="0.220000"/>
        <Entry Speed="10.691145" Draft="0.260000"/>
        <Entry Speed="11.663067" Draft="0.350000"/>
      </DraftEntries>
```

```
    </TimeStamp>
  </DraftSensor>
  <WaterlineHeight>
    <TimeStamp value="2017-195 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.510000"/>
      <ApplyFlag value="Yes"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2017-231 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.469000"/>
      <ApplyFlag value="Yes"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2017-257 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.316000"/>
      <ApplyFlag value="Yes"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2017-298 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.369000"/>
      <ApplyFlag value="Yes"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-121 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.266000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-128 00:00:00">
      <Comment value="(null)"/>
      <Latency value="0.000000"/>
      <WaterLine value="0.381000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
    <TimeStamp value="2018-142 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <WaterLine value="0.472000"/>
      <ApplyFlag value="No"/>
      <StdDev Waterline="0.000000"/>
    </TimeStamp>
  </WaterlineHeight>
  <SVPSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <DualHead value="Yes"/>
      <Offsets X="2.146000" Y="-2.923000" Z="5.022000" X2="2.450000" Y2="-2.818000" Z2=
      "5.005000"/>
      <MountAngle Pitch="-0.266000" Roll="0.327000" Azimuth="179.504000" Pitch2="-0.277000"
      Roll2="0.419000" Azimuth2="179.498000"/>
    </TimeStamp>
  </SVPSensor>
```

```
  <DepthSensor>
    <TimeStamp value="2016-278 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="em2040_300N">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.010000" Roll="-0.040000" Azimuth="0.017000"/>
        </Transducer>
        <Transducer Number="2" StartBeam="1002" Model="em2040_300N">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
    <TimeStamp value="2017-001 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="em2040_300N">
          <Manufacturer value="Kongsberg EM2040 300kHz 0.5x1_Normal Mode"/>
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
        <Transducer Number="2" StartBeam="2" Model="Unknown">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
    <TimeStamp value="2018-091 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="em2040_300N">
          <Manufacturer value="Kongsberg EM2040 300kHz 0.5x1_Normal Mode"/>
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
        <Transducer Number="2" StartBeam="2" Model="Unknown">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
    <TimeStamp value="2018-142 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="Unknown">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
  </DepthSensor>
  <TPEConfiguration>
    <TimeStamp value="2015-001 00:00:00">
      <Comment value=""/>
      <Latency value="0.000000"/>
      <Offsets>
        <MRUtoTransducer X="2.146000" Y="-2.923000" Z="5.022000" X2="2.450000" Y2="-2.818000" Z2
        ="5.005000"/>
        <NavigationToTransducer X="0.757000" Y="7.014000" Z="27.360000" X2="1.061000" Y2=
```

```
        "7.119000" Z2="27.343000"/>
        <Transducer Roll="0.000000" Roll2="0.000000"/>
        <Navigation Latency="0.000000"/>
      </Offsets>
      <StandardDeviation>
        <Motion Gyro="0.015000" HeavePercAmplitude="0.000000" Heave="0.000000" Roll="0.003000"
        Pitch="0.003000" PitchStablized="0.000000"/>
        <Position Navigation="0.100000"/>
        <Timing Transducer="0.001000" Navigation="0.001000" Gyro="0.001000" Heave="0.001000"
        Pitch="0.001000" Roll="0.001000"/>
        <SoundVelocity Measured="0.000000" Surface="0.000000"/>
        <Tide Measured="0.000000" Zoning="0.000000"/>
        <Offsets X="0.002000" Y="0.002000" Z="0.002000"/>
        <MRUAlignment Gyro="0.030000" Pitch="0.060000" Roll="0.060000"/>
        <Vessel Speed="0.000000" Loading="0.000000" Draft="0.000000" DeltaDraft="0.000000">
          <StDevComment value="(null)"/>
        </Vessel>
      </StandardDeviation>
    </TimeStamp>
  </TPEConfiguration>
</HIPSVesselConfig>
```

| | S222_EM2040_2018 | | | | | |
|---|---|---|---|---|---|---|
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | | | |
| POS Ref to IMU | 0.005 | -0.006 | 0.089 | | | |
| POS Ref to Primary GPS | -9.937 | 1.389 | -22.421 | | | |
| POS IMU to Ref Frame | 0 | 0 | 0 | | | |
| | | | | | | |
| | X (+FWD) | Y (+STBD) | Z (+DOWN) | Roll | Pitch | Yaw |
| Kongs TX Offset | -2.923 | 2.146 | 5.022 | 0.327 | -0.266 | 179.504 |
| Kongs RX Offset | -2.818 | 2.45 | 5.005 | 0.419 | -0.277 | 179.498 |
| Kongs Waterline | 0 | 0 | 0.302 | | | |
| | | | | | | |
| | X (+STBD) | Y (+FWD) | Z (+DOWN) | Pitch | Roll | Yaw |
| Caris Trans 1 | | | | | | |
| Caris SVP 1 | | | | | | |
| Caris Trans 2 | | | | | | |
| Caris SVP 2 | | | | | | |
| Caris Heave | -2.146 | 2.923 | -5.022 | | | |
| Caris Waterline | 0 | 0 | 0.307 | | | |
| | | | | | | |
| | Heave | Pitch | Roll | Draft | Waterline | |
| Caris Apply Flags | No | No | No | Yes | No | |

Offset Checks:

| | |
|---|---|
| Caris HVF SVP2 and Kongs RX are equal | No |
| Caris HVF SVP1 and .all Kongs TX are equal | No |
| Caris HVF Heave is opposite of .all Kongsberg TX Offset with HVF Apply = No | Yes |
| Caris HVF Waterline has a value | Yes |
| POS Primary GPS Antenna Value above IMU | Yes |
| RP at IMU | Yes |

```xml
<?xml version="1.0"?>
<HIPSVesselConfig Version="2.0">
  <VesselShape>
    <PlanCoordinates>
      <Entry X="-6.246000" Y="-45.000000"/>
      <Entry X="8.754000" Y="-45.000000"/>
      <Entry X="8.754000" Y="10.000000"/>
      <Entry X="1.254000" Y="18.000000"/>
      <Entry X="-6.246000" Y="10.000000"/>
      <Entry X="-6.246000" Y="-45.000000"/>
    </PlanCoordinates>
    <ProfileCoordinates>
      <Entry Y="-45.000000" Z="3.000000"/>
      <Entry Y="-45.000000" Z="-4.000000"/>
      <Entry Y="10.000000" Z="-4.000000"/>
      <Entry Y="18.000000" Z="3.000000"/>
      <Entry Y="-45.000000" Z="3.000000"/>
    </ProfileCoordinates>
    <RP Length="45.000000" Width="8.754000" Height="4.000000"/>
  </VesselShape>
  <DepthSensor>
    <TimeStamp value="2015-001 00:00:00">
      <Latency value="0.000000"/>
      <SensorClass value="Swath"/>
      <TransducerEntries>
        <Transducer Number="1" StartBeam="1" Model="Unknown">
          <Offsets X="0.000000" Y="0.000000" Z="0.000000" Latency="0.000000"/>
          <MountAngle Pitch="0.000000" Roll="0.000000" Azimuth="0.000000"/>
        </Transducer>
      </TransducerEntries>
    </TimeStamp>
  </DepthSensor>
  <HeaveSensor>
    <TimeStamp value="2015-001 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000" Heave="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
  </HeaveSensor>
  <NavSensor>
    <TimeStamp value="2015-001 00:00:00">
      <Latency value="-3.800000"/>
      <Ellipse value="WG84"/>
      <Offsets X="0.000000" Y="0.000000" Z="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="Applanix"/>
      <Model value="v4"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
  </NavSensor>
  <PitchSensor>
    <TimeStamp value="2015-001 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Pitch="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
      <SerialNumber value="(null)"/>
    </TimeStamp>
```

```
  </PitchSensor>
  <RollSensor>
    <TimeStamp value="2015-001 00:00:00">
      <Latency value="0.000000"/>
      <ApplyFlag value="No"/>
      <Offsets Roll="0.000000"/>
      <Comment value="(null)"/>
      <Manufacturer value="(null)"/>
      <Model value="(null)"/>
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# Appendix 8:

# HSRR documentation

Updated: 6/5/2018

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Marine and Aviation Operations,
Marine Operation Center-Atlantic, NOAA Ship *Thomas Jefferson*
Norfolk, Virginia 23510

May 4, 2018

MEMORANDUM FOR: Captain Richard T. Brennan, NOAA
Chief, Hydrographic Surveys Division

FROM: Commander Chris van Westendorp, NOAA
Commanding Officer, NOAA Ship *Thomas Jefferson*

SUBJECT: NOAA Ship *Thomas Jefferson* Hydrographic Systems Status Summary

The hydrographic systems of NOAA Ship *Thomas Jefferson* were reviewed in accordance with the Office of Coast Survey Field Procedures Manual (FPM) Hydrographic Systems Readiness Review procedures. *Thomas Jefferson* ran system certification operations in the lower Chesapeake Bay and Elizabeth River in March and April 2018. After some mechanical downtime and delays in ship schedule, Hydrographic Systems Readiness Review for all platforms was completed on 25 April 2018.

All certification tests were conducted and reviewed by a Hydrographic Systems Review Team comprised of the following people:

LT Anthony Klemm, Operations Officer
LT Charles Wisotzkey, Operations Officer in Training
Chief Hydrographic Survey Technician Allison Stone
Clinton Marcus, Physical Scientist, Atlantic Hydrographic Branch
*Thomas Jefferson* Survey Department
*Thomas Jefferson* Junior Officers

The team installed and tested all systems except as noted below. The appropriate calibrations, checks, and tests have been performed, and all tested satisfactorily except as noted below.

The Review Team's findings are summarized in this memorandum and reflect the condition of *Thomas Jefferson*'s hydrographic systems on the review date. These findings have been divided into three categories of deficiencies:

**CATEGORY 1** – These deficiencies indicate the failure or absence of vital equipment or preparations of systems essential to acquisition and/or processing of hydrographic data. The vessel will be required to cease or limit hydrographic survey operations due to the following deficiencies:

There are no Category 1 deficiencies.

**CATEGORY 2 –** These deficiencies indicate noncompliance with established policies, directives, instructions, or accepted hydrographic practice not addressed under Category 1. The following deficiencies shall be corrected in as timely a manner as funding, time, and/or professional assistance permit:

1. The ship's Kongsberg EM710 and EM2040 multibeam echosounders continue to operate in a degraded mode for normal hydrographic survey operations. Hydrographic Systems Technical Branch (HSTB) has issued guidance recommending limiting the EM710 and EM2040 to a 90° swath width to minimize the impact of an outer beam artifact. The source is as yet unknown, but is suspected to be bubble sweepdown or another oceanographic influence. Limiting the swath minimizes effects of the artifact, but severely limits the capability of both systems to operate as intended. The most pronounced effect on day-to-day operations is lack of coverage of the Side Scan Sonar nadir gap in shallower water.

**CATEGORY 3 –** These deficiencies are associated with observations during the course of the review which merit consideration for corrective actions. These observations are included for review and dialogue related to potential problem areas and hydrographic operational efficiency. It is important to assure that resources (funds, skills, and time) are available at the operating level in order to meet the needs identified in this report and to sustain the ef ficient operation, upkeep, and repair of the field unit's hydrographic systems.

1. The ship's Moving Vessel Profiler (MVP) is showing signs of age. At present, the MVP functions adequately, but is no longer supported by the manufacturer and has fairly significant external corrosion. Additionally, its cable is down to 160m, of which 120m is usable. Its replacement is requested as soon as funds are available.
2. The ship's Side Scan Sonar winch is well past its useful life. Parts are becoming more scarce as time goes on, and preservation of it against the corrosion that has already set in will be a major undertaking by deck department. Its replacement is requested as soon as funds are available.
3. The ship's Klein 5000 Side Scan Sonars were sent to the manufacturer for health checks. All, except for Klein 5500 (S/N 319) which was serviced in 2017, perform below the original manufacturers performance standards, and are due for service at the end of the 2018 field season.

The following is a list of calibrations for each platform associated with *Thomas Jefferson*. Calibrations not completed appear in red.

*Thomas Jefferson* (S-222):
- CTD calibration
- Surface Sound Velocity calibration (includes SV&P's used for MVP system)
- CTD Comparison – includes probe mounted in MVP, and all CTD's aboard.
- GAMS calibration

- Ellipsoidally Referenced Dynamic Draft (average from years past used in Hips Vessel File, HVF, per HSTB guidance)
- Multibeam Patch Test: EM2040 and EM710
- Multibeam vs leadline comparison
- Reference Surface
- Side Scan Sonar Certification: 50/75/100 meters

HSL 2903:
- CTD Comparison
- GAMS calibration
- Ellipsoidally Referenced Dynamic Draft (average from years past used in HVF per HSTB guidance)
- Multibeam Patch Test: 200/400 khz
- Multibeam vs. leadline comparison
- Reference Surface: 200/400 khz
- Multibeam vs Vertical beam vs leadline comparison
- Side Scan Sonar Calibration: 50/75/100 meters

HSL 2904:
- CTD Comparison
- GAMS calibration
- Ellipsoidally Referenced Dynamic Draft (average from years past used in HVF per HSTB guidance)
- Multibeam Patch Test: 200/400 khz
- Multibeam vs. leadline comparison
- Reference Surface: 200/400 khz
- Multibeam vs Vertical beam vs leadline comparison
- Side Scan Sonar Calibration: 50/75/100 meters

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**
Office of Coast Survey
1315 East West Highway, SSMC3, Silver Spring, MD 20910

**FROM:** Kathryn Ries
Deputy Director

**TO:** The Record

**REFERENCE:** Environmental review of proposed Hydrographic Systems Readiness Review projects for various NOAA platforms - 2018

For our hydrographic fleet to continue its critical service to the country, NOAA must ensure that its vessels are equipped with the appropriate survey gear, that the gear is operating correctly, and that ship and boat crews are trained to perform their duties safely and efficiently. To this end, NOAA hydrographic vessels undertake Hydrographic Systems Readiness Review (HSRR) projects annually. This memorandum summarizes the timing, location, and nature of these activities, and determines if they fall within the boundaries established by the Office of Coast Survey environmental compliance program.

# 1.0 Background

To ensure that the necessary HSRR work is undertaken in compliance with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the National Historic Preservation Act (NHPA), and the Coastal Zone Management Act (CZMA), Coast Survey has consulted with the relevant regulatory authorities regarding the broad testing and training approaches that Coast Survey uses (i.e., equipment, methods, platforms, locations, etc.). This memorandum documents how the specific proposed HSRR projects for 2018 comply with the broad, programmatic consultations that Coast Survey has conducted with the National Marine Fisheries Service (NMFS), the Fish and Wildlife Service (FWS), State Historic Preservation Officers (SHPOs), and state coastal zone management agencies. This memorandum also considers how these HSRR projects comply with the 2013 Programmatic Environmental Assessment (PEA) for Coast Survey Operations.

A summary of these HSRR projects is presented in Table 1 below.

**Table 1: Summary of 2018 HSRR Projects**

<table>
<tr><th>Platform</th><th>Location(s)</th><th>Activities</th></tr>
<tr><td>NOAA Ship Fairweather</td><td>Yaquina River, OR; Astoria Canyon, WA-OR; Puget Sound, WA; and Juan de Fuca, WA</td><td rowspan="4">All ships will or could perform the following:<br>1. Vessel Operation (including launches)<br>2. Echo Sounder Operation<br>3. Sound Speed Data Collection<br>4. Operation of Drop/Towed Cameras and Video Systems<br>5. Anchoring</td></tr>
<tr><td>NOAA Ship Rainier</td><td>Yaquina River, OR; Puget Sound, WA; and Juan de Fuca, WA</td></tr>
<tr><td>NOAA Ship Thomas Jefferson</td><td>Norfolk, VA and Virginia Offshore</td></tr>
<tr><td>NOAA Ship Ferdinand Hassler</td><td>Norfolk, VA</td></tr>
</table>

### 1.1 Best Management Practices

In the course of the HSRR projects, Coast Survey would adhere to Best Management Practices (BMPs, see Appendix A) based on those practices agreed to between Coast Survey and the NMFS Office of Protected Resources in the course of the Endangered Species Act section 7 consultation that was documented in the April 2013 Biological Opinion[1] and updated in a May 12, 2017 Concurrence Letter for Revised Protective Measures.[2]

These projects are addressed in more detail below.

## *2.0 NOAA Ship Fairweather*

The NOAA Office of Marine and Aviation Operations (OMAO) and the Office of Coast Survey propose to conduct testing and calibration of echo sounders on the NOAA Ship *Fairweather* at multiple times and places in 2018. The locations and timing of these activities are shown in Table 2 below.

**Table 2: Time and Location of *Fairweather* HSRR projects in 2018**

| Location | Time Frame |
|---|---|
| Yaquina River, OR | March to April 2018 |
| Astoria Canyon, WA-OR | March to April 2018 |
| Puget Sound, WA | April to May 2018 |
| Juan de Fuca, WA | March to April 2018 |

As with all activities at sea, the date of the proposed action could be affected by poor weather, equipment difficulties, or other unforeseen circumstances.

*Fairweather* will leave port from Newport, Oregon, and proceed to the HSRR locations shown in Figures 1, 2, and 3 below.

[1] *Biological and Conference Opinion for the Office of Coast Survey, National Ocean Service, NOAA*, April 20, 2013

[2] *Concurrence Letter on Revised Protective Measures to be followed during Coast Survey Operations*, May 12, 2017

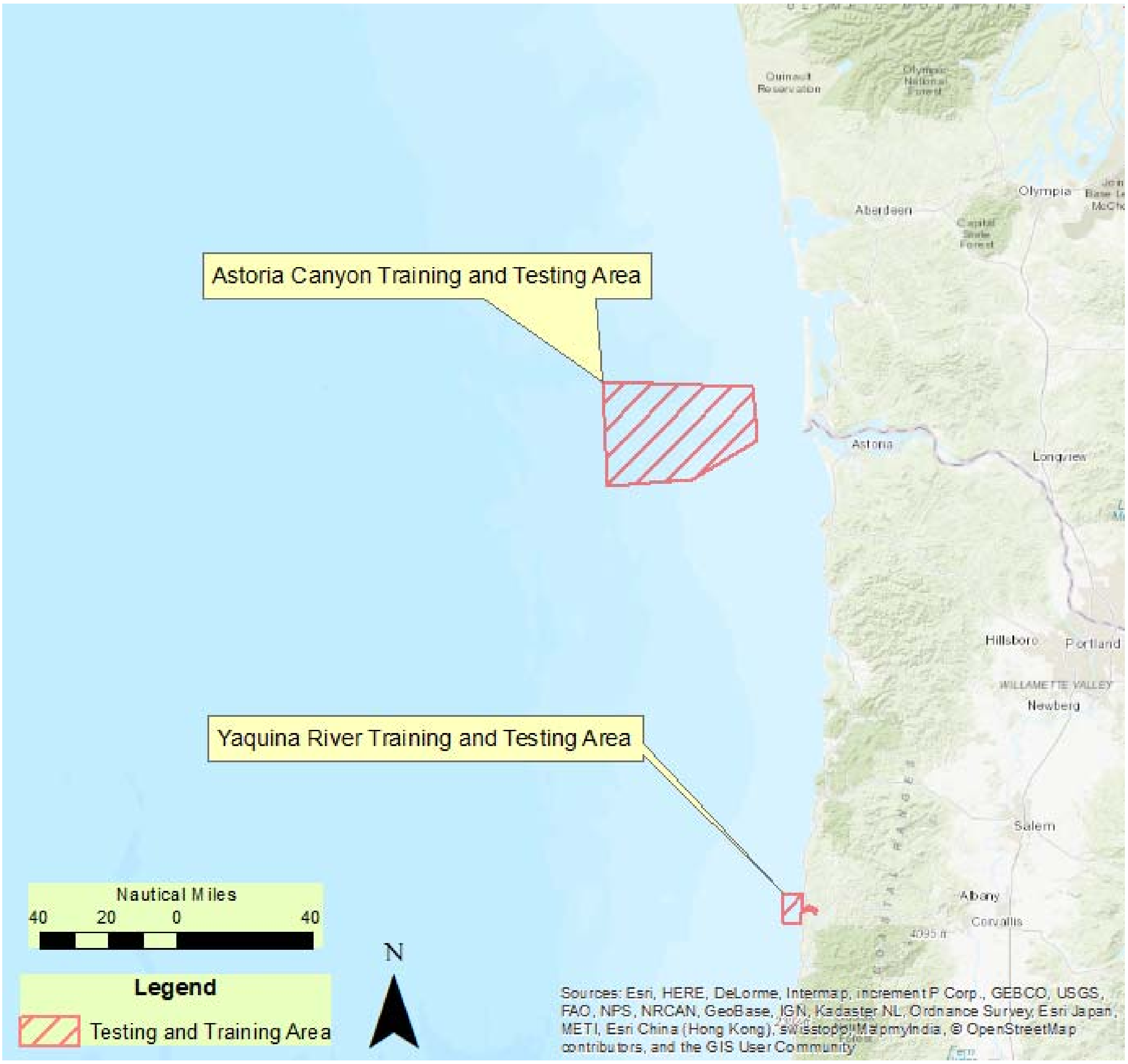


**Figure 1: Yaquina River and Astoria Canyon testing and training areas to be used by *Fairweather***

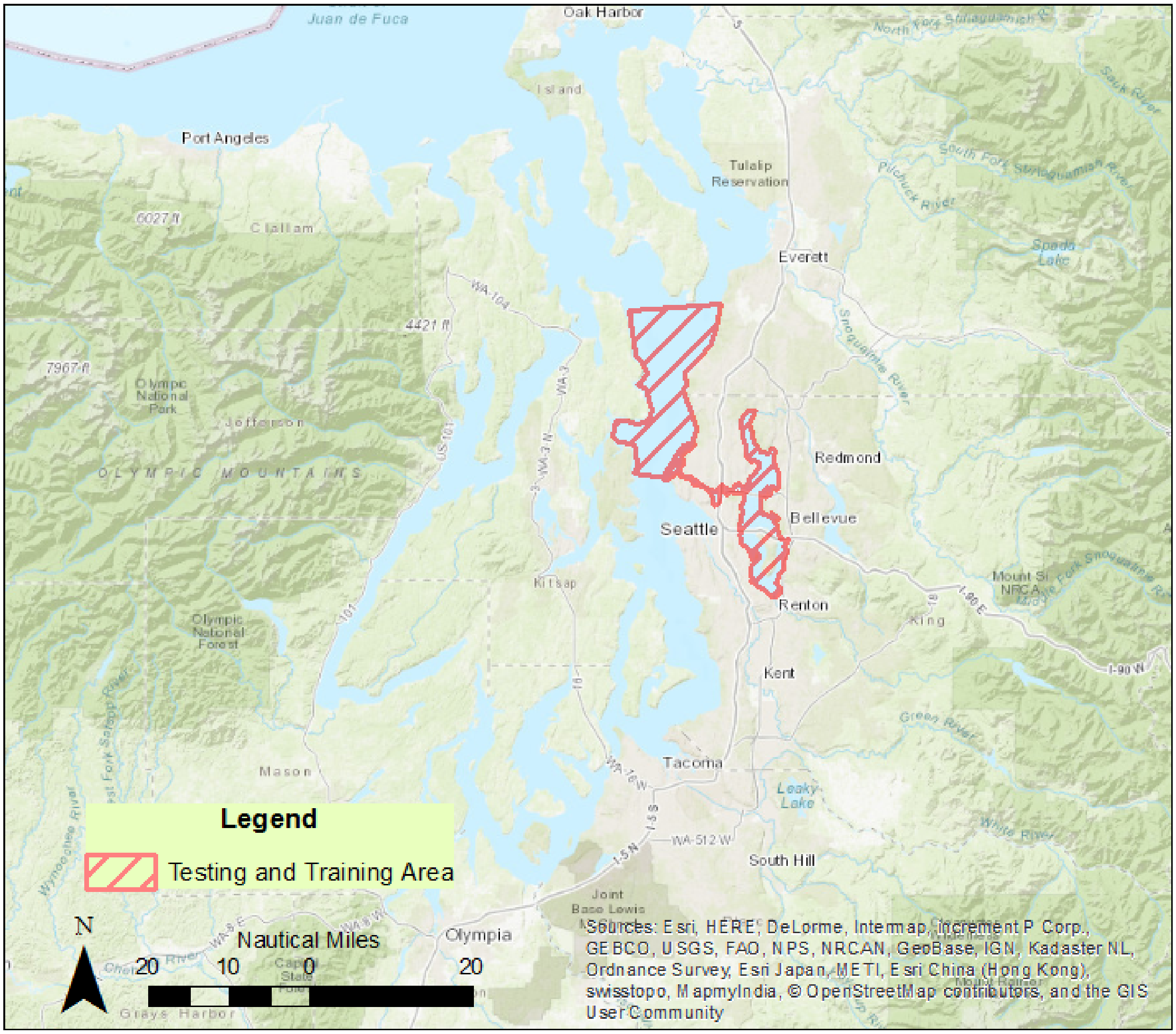


**Figure 2: Puget Sound testing and training area to be used by *Fairweather***

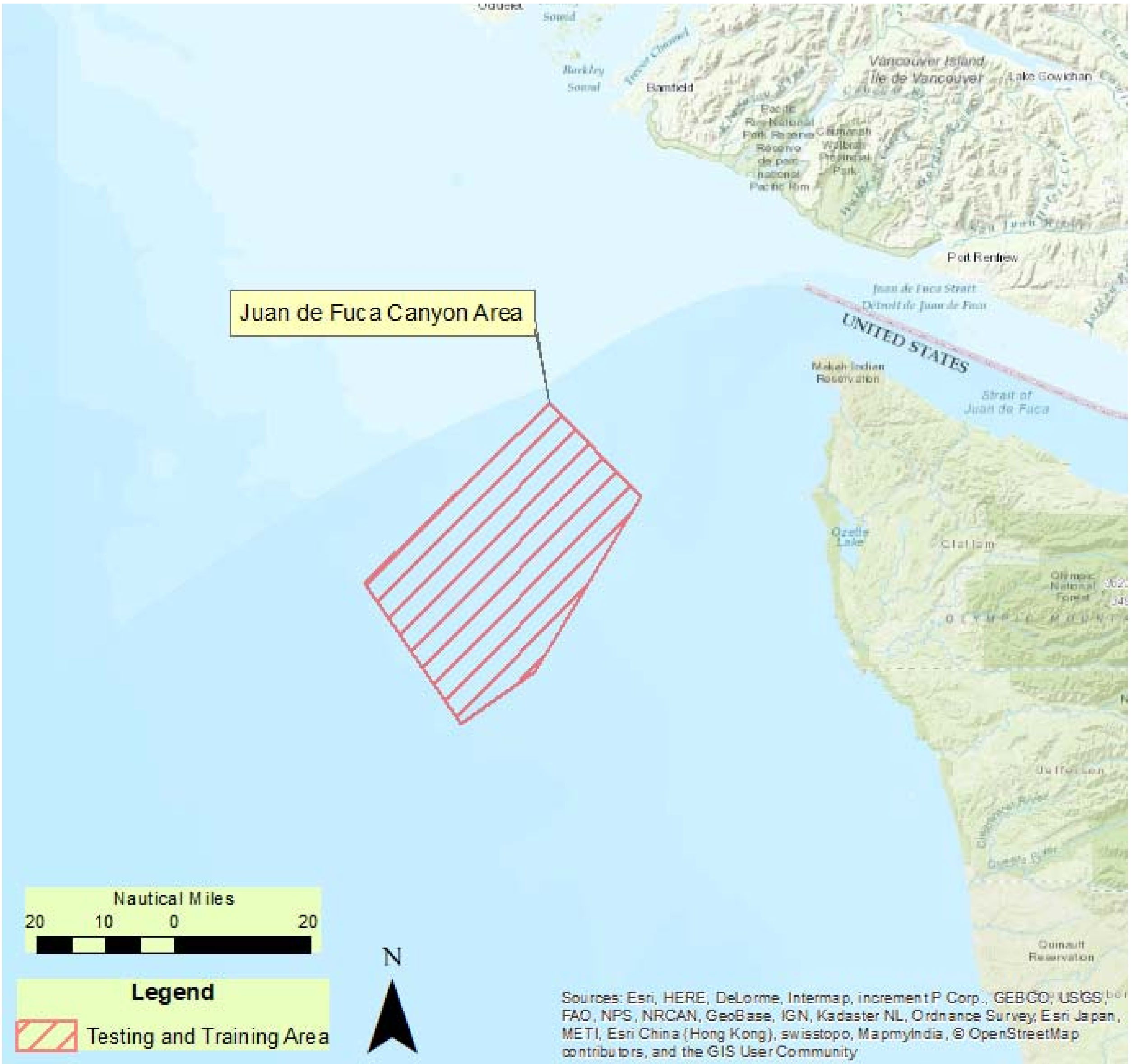


**Figure 3: Juan de Fuca testing and training area to be used by *Fairweather***

The proposed action will take place only in limited areas within the wider locations shown – Coast Survey will not ensonify the entire delineated areas. *Fairweather* will engage in the following activities:

1. Vessel Operation (including launches)
2. Echo Sounder Operation
3. Sound Speed Data Collection
4. Operation of Drop/Towed Cameras and Video Systems
5. Anchoring

The echo sounders to be tested include Side scan sonar and multibeam systems ranging in frequencies from 40 to 455 kilohertz (kHz).

## 2.1 NEPA Compliance for *Fairweather* HSRR Projects

Coast Survey relies on the 2013 Programmatic Environmental Assessment for Coast Survey Operations for compliance with NEPA. All of the proposed activities fall within the scope of this PEA, except for the operation of one echo sounder system. Specifically, *Fairweather* intends to operate multibeam systems at frequencies as low as 40 kHz. This is slightly lower than the 50 kHz systems described and analyzed in the PEA. However, the use of this system is not expected to have a greater impact than 50 kHz systems, as explained below.

A review of the known ranges of marine mammals indicates that 26 species could potentially be located in the HSRR areas. Table 3 shows those marine mammals classified as low-frequency cetaceans with hearing ranges that are well below the frequencies to be used during the proposed action.

**Table 3: Low-Frequency Hearing Cetaceans Potentially Located in the Project Areas**

| Marine Mammal Species[3] | Status | Hearing Frequency Range[4] |
|---|---|---|
| Blue Whale | Endangered (ESA); Depleted (MMPA) | 7 Hz to 35 kHz |
| Fin whale | | |
| Humpback Whale | | |
| Sei whale | | |
| Gray Whale | | |
| North Pacific Right Whale | | |
| Minke Whale | NA | |

These species could be located in the project area, but would not be able to perceive the sound produced by the echo sounders to be used, because the highest frequency they can hear (35 kHz) is below the lowest frequency that would be emitted during the test (40 kHz). Therefore there is no potential for these species to be affected by the echo sounders to be used.

Table 4 shows those marine mammals classified as mid- and high-frequency cetaceans, as well as pinnipeds. These animals have hearing ranges higher than 40 kHz.

---

[3] *http://www.nmfs.noaa.gov/pr/species/mammals/*

[4] Southall *et al.* 2007 and Parks *et al.* 2007

**Table 4: Frequency Ranges of Other Marine Mammals Potentially Located in the Project Areas**

| Marine Mammal Species[5] | Status[3] | Frequency Range[6] |
|---|---|---|
| Harbor Porpoise | NA | 75 Hz to 75 kHz |
| California Sea Lion | NA | |
| Harbor Seal | NA | |
| Steller Sea Lion | NA in the project areas | |
| Northern Elephant Seal | NA | |
| Baird's Beaked Whale | Depleted (MMPA) | 150 Hz to 160 kHz |
| Cuvier's Beaked Whale | NA | |
| False Killer Whale | NA in the project areas | |
| Risso's Dolphin | NA | |
| Short-Beaked Common Dolphin | NA | |
| Short-Finned Pilot Whale | NA | |
| Northern Right Whale Dolphin | NA in the project areas | |
| Killer Whale | Endangered (ESA), Depleted (MMPA) | |
| Pacific White-Sided Dolphin | NA | |
| Stejneger's Beaked Whale | NA | |
| Sperm Whale | Endangered (ESA); Depleted (MMPA) | |
| Dwarf Sperm Whale | NA | 200 Hz to 180 kHz |
| Pygmy Sperm Whale | NA | |
| Dall's Porpoise | NA | |

None of the species listed in Table 4 have a maximum hearing frequency between 40 and 50 kHz – that is, the use of the 40 kHz echo sounder will not expose any additional marine mammals to acoustic impacts, compared to the 50 kHz equipment that is specified in the Coast Survey PEA.

Coast Survey would observe the BMPs agreed to between Coast Survey and NMFS to reduce the potential impacts to marine mammals and threatened or endangered species from both echo sounder use and vessel strike. Based on the nature of the action and adherence to these BMPs, the impacts of the proposed action on marine mammals is consistent with those impacts presented in the Coast Survey PEA. The Coast Survey PEA concluded that underwater sound associated with hydrographic survey operations may lead to temporary avoidance behavior (acoustic harassment), but is unlikely to injure marine mammals in the long term.

Based on these determinations, Coast Survey has determined that the proposed HSRR projects for *Fairweather* are within the scope of the 2013 Coast Survey PEA.

---

[5] *http://www.nmfs.noaa.gov/pr/species/mammals/*

[6] Southall *et al.* 2007 and Parks *et al.* 2007

### 2.2 ESA, NHPA, and CZMA Compliance for *Fairweather* HSRR Projects

Coast Survey has complied with the requirements of these laws for HSRR projects by coordinating operations in the Yaquina River, Puget Sound, Juan de Fuca, and Astoria Canyon HSRR areas for the years 2018 through 2022 with the relevant regulatory agencies, as described below.

**Table 5: Environmental Compliance Correspondence for the Southern Chesapeake and Norfolk Canyon HSRR Areas**

| Law | Document | Sent to | Concurrence Received on |
|---|---|---|---|
| ESA (NMFS species) | 2013 Coast Survey PEA | NMFS | April 20, 2013 (Biological Opinion) and May 12, 2017 (Letter of Concurrence for Revised Best Management Practices) |
| ESA (FWS species) | Biological Assessment | FWS | January 18, 2018 (Oregon); January 31, 2018 (Washington) |
| NHPA | Section 106 Consultation letter | Washington SHPO* | 30-day comment period elapsed on January 22, 2018; no response received |
| CZMA | Federal Consistency Determination | Oregon Coastal Management Program; Washington Department of Ecology | January 18, 2018 (Oregon); December 1, 2017 (Washington) |
| ***Oregon activities were determined to have "no potential to effect" historic properties, and therefore no coordination with the Oregon SHPO was required.** | | | |

Coast Survey has evaluated the nature, timing, extent, and location of the activities proposed by *Fairweather*, and has determined that these activities fall within the scope of the documents and concurrences mentioned in Table 5 above. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 40 kHz and higher for multibeam and side scan sonar systems) that are addressed in the correspondence with the appropriate regulatory agencies.

Therefore, Coast Survey has determined that these activities are in compliance with the ESA, NHPA, and CZMA.

## *3.0 NOAA Ship Rainier*

OMAO and the Office of Coast Survey propose to conduct testing and calibration of echo sounders from *Rainier* at multiple times and places in 2018. The locations and timing of these activities are shown in Table 6 below.

**Table 6: Time and Location of *Rainier* HSRR Projects in 2018**

| Location | Time Frame |
|---|---|
| Yaquina River, OR | March 5 to April 2, 2018 |
| Puget Sound, WA | April 2 to 8, 2018 |
| Juan de Fuca, WA | April 2018 |

As with all activities at sea, the date of the proposed action could be affected by poor weather, equipment difficulties, or other unforeseen circumstances.

*Rainier* will leave port from Newport, Oregon, and proceed to the HSRR locations shown in Figures 4, 5, and 6 below.

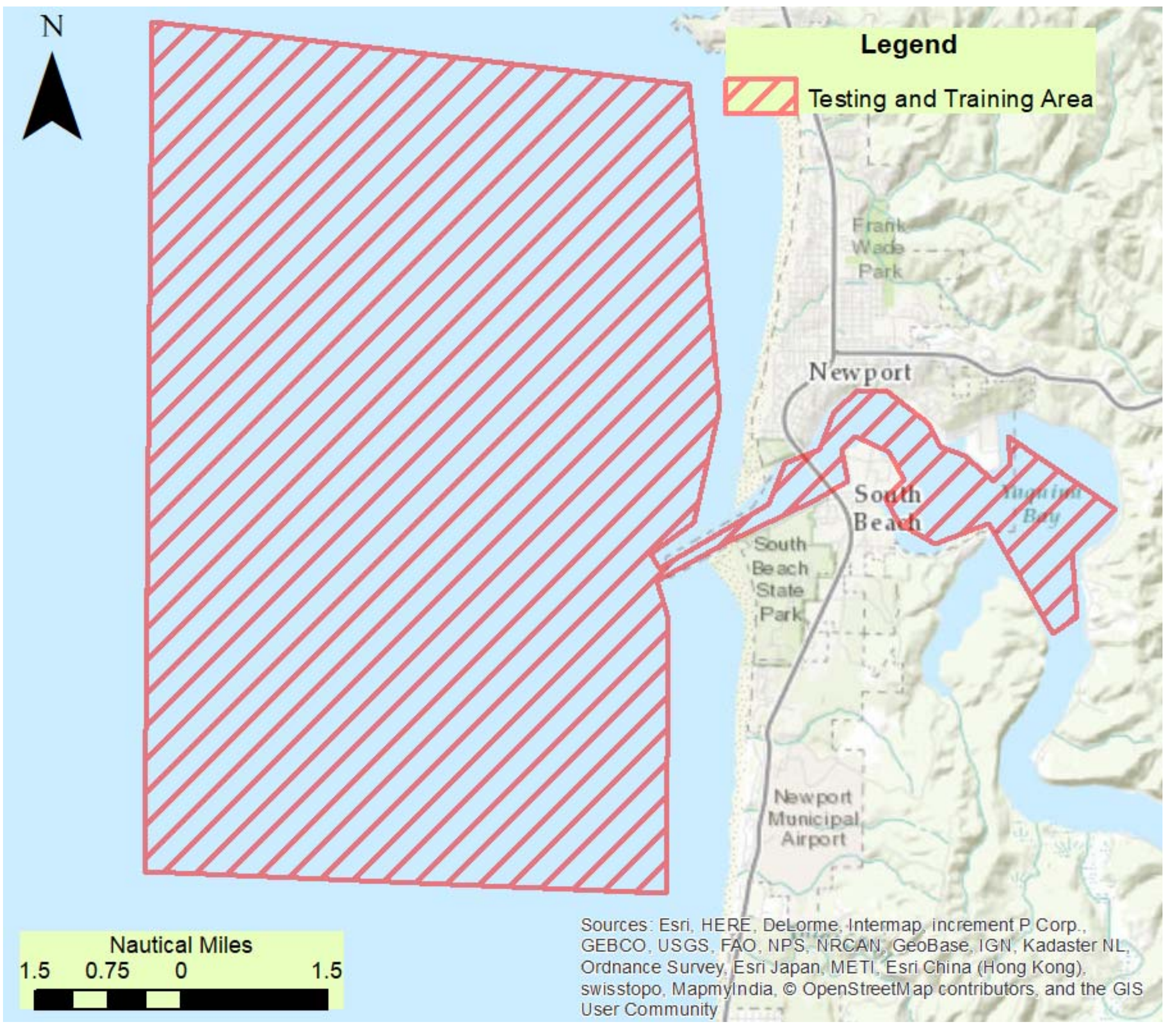


**Figure 4: Yaquina River testing and training area to be used by *Rainier***

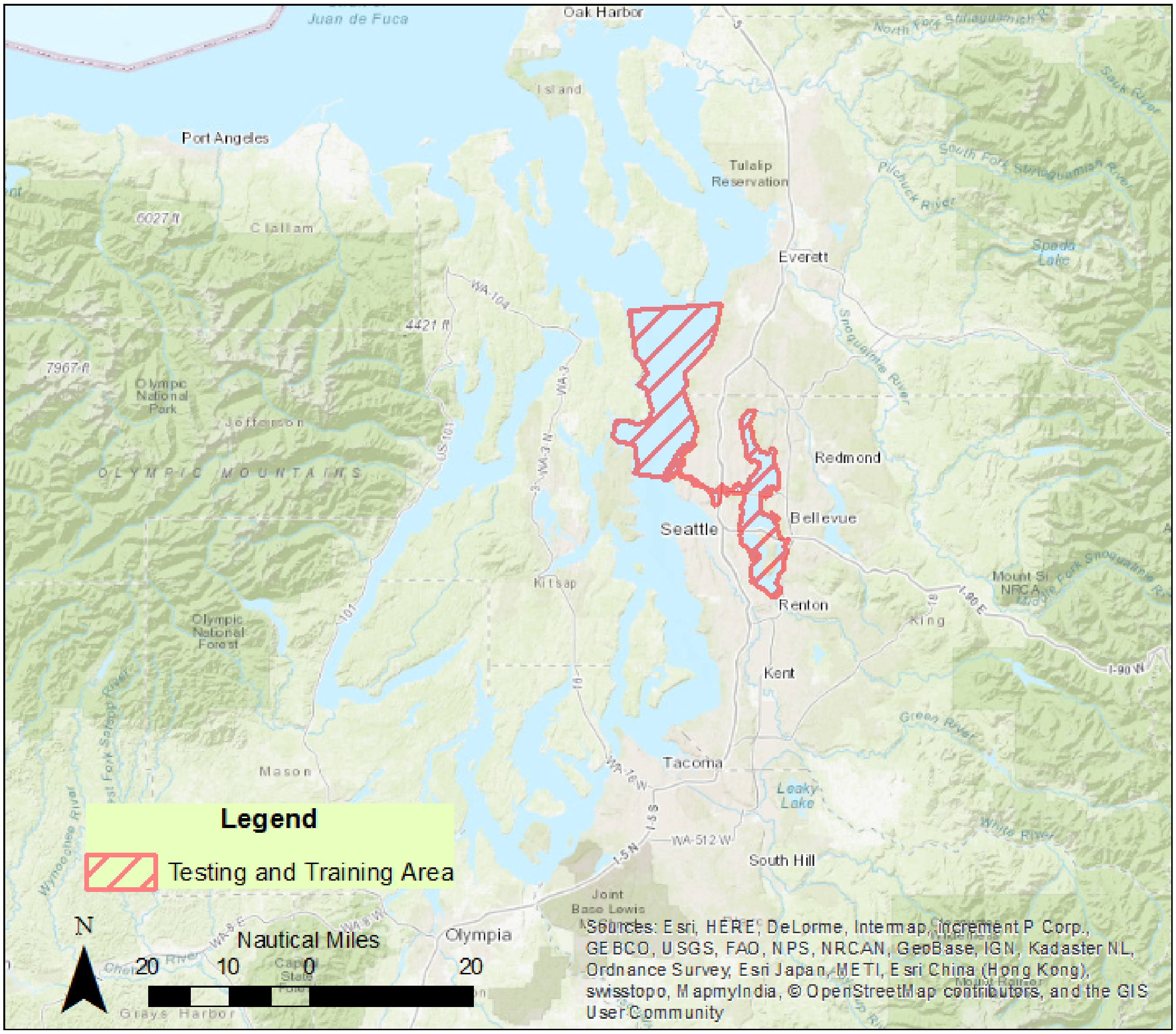


**Figure 5: Puget Sound testing and training area to be used by *Rainier***

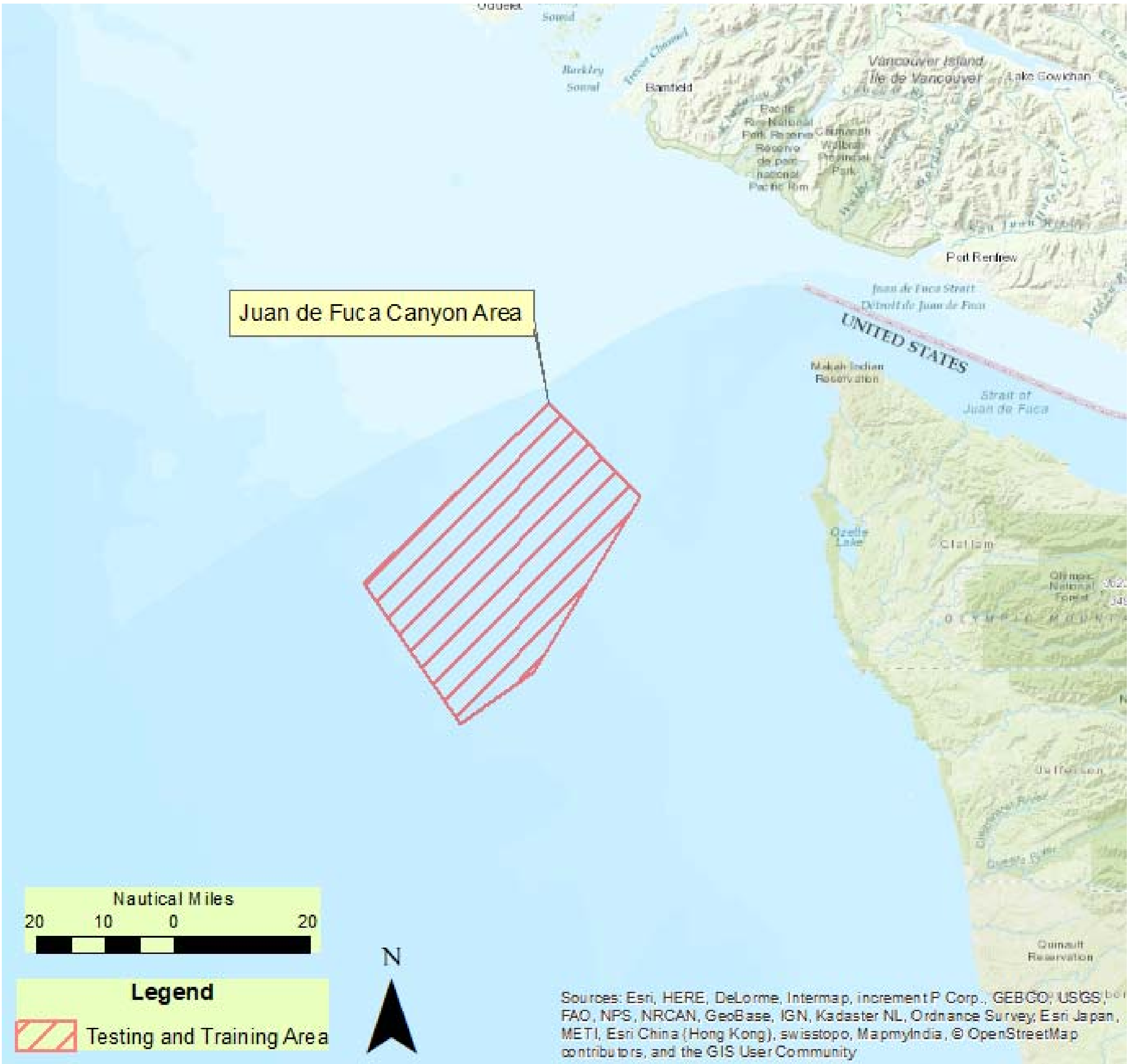


**Figure 6: Juan de Fuca testing and training area to be used by *Rainier***

The proposed action will take place only in limited areas within the wider locations shown – Coast Survey will not ensonify the entire delineated area.

*Rainier* will engage in the following activities:

1. Vessel Operation (including launches)
2. Echo Sounder Operation
3. Sound Speed Data Collection
4. Operation of Drop/Towed Cameras and Video Systems
5. Anchoring

Echo sounders to be used by *Rainier* would include single beam systems operating at frequencies as low as 24 kHz, side scan sonar systems operating as low as 300 kHz, and multibeam systems operating as low as 70 kHz.

### 3.1 NEPA Compliance for *Rainier* HSRR Projects

Coast Survey relies on the 2013 Programmatic Environmental Assessment for Coast Survey Operations for compliance with NEPA. All of the proposed activities fall within the scope of this PEA. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 50 kHz and higher for multibeam and side scan sonar systems) that are addressed in the Coast Survey PEA.

Based on these determinations, Coast Survey has determined that the proposed HSRR projects for *Rainier* are within the scope of the 2013 Coast Survey PEA.

### 3.2 ESA, NHPA, and CZMA Compliance for *Rainier* HSRR Projects

Coast Survey has complied with the requirements of these laws for HSRR projects by coordinating operations in the Yaquina River, Puget Sound, and Juan de Fuca HSRR areas for the years 2018 to 2022 with the relevant regulatory agencies, as described in Table 7 below.

**Table 7: Environmental Compliance Correspondence for the Yaquina River, Juan de Fuca, and Puget Sound HSRR Areas**

| Law | Document | Sent to | Concurrence Received on |
|---|---|---|---|
| ESA (NMFS species) | 2013 Coast Survey PEA | NMFS | April 20, 2013 (Biological Opinion) and May 12, 2017 (Letter of Concurrence for Revised Best Management Practices) |
| ESA (FWS species) | Biological Assessment | FWS | January 18, 2018 (Oregon); January 31, 2018 (Washington) |
| NHPA | Section 106 Consultation letter | Washington SHPO* | 30-day comment period elapsed on January 22, 2018; no response received |
| CZMA | Federal Consistency Determination | Oregon Coastal Management Program; Washington Department of Ecology | January 18, 2018 (Oregon); December 1, 2017 (Washington) |
| ***Oregon activities were determined to have "no potential to effect" historic properties, and therefore no coordination with the Oregon SHPO was required.** | | | |

Coast Survey has evaluated the nature, timing, extent, and location of the activities proposed by *Rainier*, and has determined that these activities fall within the scope of the documents and concurrences mentioned in Table 7 above. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 40 kHz and higher for multibeam and side scan sonar systems) that are addressed in the correspondence with the appropriate regulatory agencies.

Therefore, Coast Survey has determined that these activities are in compliance with the ESA, NHPA, and CZMA.

# *4.0 NOAA Ship Thomas Jefferson*

OMAO and the Office of Coast Survey propose to conduct testing and calibration of echo sounders on the NOAA Ship *Thomas Jefferson* from March 6 to April 6, 2018. As with all activities at sea, the dates of the work could be affected by poor weather, equipment difficulties, or other unforeseen circumstances.

*Thomas Jefferson* will leave port from Norfolk, Virginia, and proceed to the HSRR locations shown in Figure 7 below.

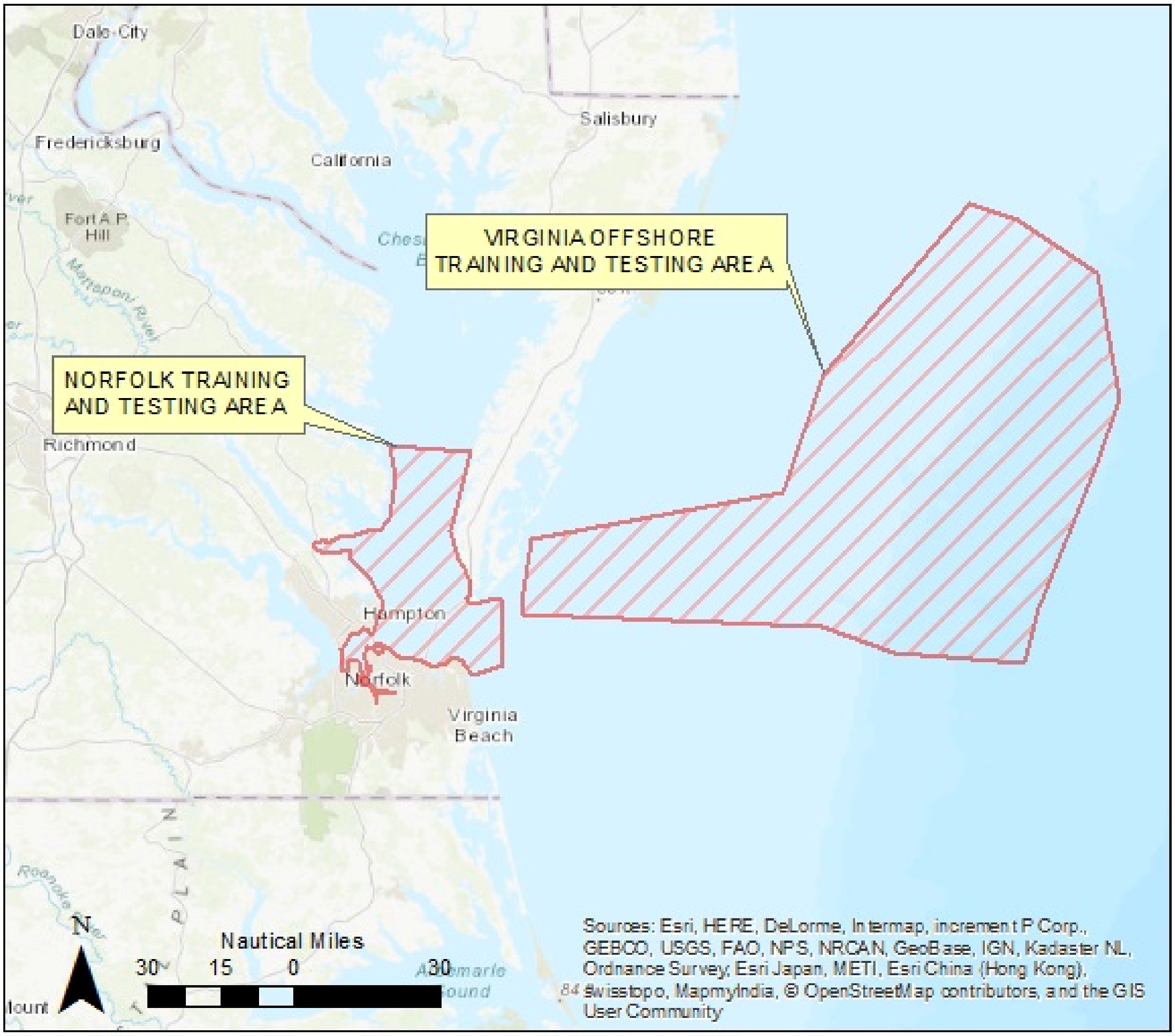


**Figure 7: The testing and training areas to be used by *Thomas Jefferson* in 2018**

The proposed action will take place only in limited areas within the wider locations shown – Coast Survey will not ensonify the entire delineated area.

*Thomas Jefferson* will engage in the following activities:

1. Vessel Operation (including launches)
2. Echo Sounder Operation
3. Sound Speed Data Collection
4. Operation of Drop/Towed Cameras and Video Systems
5. Anchoring

Echo sounders to be used by *Thomas Jefferson* would include single beam systems operating at frequencies as low as 12 kHz, and multibeam systems operating as low as 40 kHz.

### 4.1 NEPA Compliance for *Thomas Jefferson* HSRR Projects

Coast Survey relies on the 2013 Programmatic Environmental Assessment for Coast Survey Operations for compliance with NEPA. All of the proposed activities fall within the scope of this PEA, except for the operation of one echo sounder system. Specifically, *Thomas Jefferson* intends to operate multibeam systems at frequencies as low as 40 kHz. This is slightly lower than the 50 kHz systems described and analyzed in the PEA. However, the use of this system is not expected to have a greater impact than 50 kHz systems, as explained below.

A review of the known ranges of marine mammals indicates that 34 species could potentially be located in the survey area. Table 8 shows those marine mammals classified as low-frequency cetaceans with hearing ranges that are well below the frequencies to be used during the proposed action.

**Table 8: Low-Frequency Hearing Cetaceans Potentially Located in the Project Areas**

| Marine Mammal Species[7] | Status | Hearing Frequency Range[8] |
|---|---|---|
| Blue Whale | Endangered (ESA); Depleted (MMPA) | 7 Hz to 35 kHz |
| Fin whale | | |
| Humpback Whale | | |
| Sei whale | | |
| Bryde's Whale | NA in the project area[9] | |
| Minke Whale | NA | |
| North Atlantic Right Whale | Endangered (ESA); Depleted (MMPA) | |

These species could be located in the project area, but would not be able to perceive the sound produced by the echo sounders to be used, because the highest frequency they can hear (35 kHz) is well below the lowest frequency that would be emitted during the test (40 kHz). Therefore there is no potential for these species to be affected by the echo sounders to be used.

Table 9 shows those marine mammals classified as mid- and high-frequency cetaceans, as well as pinnipeds. These animals have hearing ranges higher than 40 kHz.

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[7] *http://www.nmfs.noaa.gov/pr/species/mammals/*

[8] Southall *et al.* 2007 and Parks *et al.* 2007

[9] Distinct Population Segments (DPS) of these species are listed as endangered or threatened under the ESA or are listed as depleted under the MMPA, but these DPSs are not located in or near the project areas.

**Table 9: Frequency Ranges of Other Marine Mammals Potentially Located in the Project Areas**

| Marine Mammal Species[10] | Status | Frequency Range[11] |
|---|---|---|
| Harbor Porpoise | NA | 75 Hz to 75 kHz |
| Gray Seal | NA | |
| Harbor Seal | NA | |
| Killer Whale | NA in the project area[12] | Up to 100 kHz |
| Atlantic Spotted Dolphin | NA | 150 Hz to 160 kHz |
| Atlantic White-Sided Dolphin | NA | |
| Bottlenose Dolphin | Depleted (MMPA) | |
| Cuvier's Beaked Whale | NA | |
| Clymene Dolphin | NA | |
| Gervais' Beaked Whale | Depleted (MMPA) | |
| Pantropical Spotted Dolphin | NA in the project area [4] | |
| Risso's Dolphin | NA | |
| Rough-Toothed Dolphin | NA | |
| Short-Beaked Common Dolphin | NA | |
| Spinner Dolphin | NA in the project area [4] | |
| Short-Finned Pilot Whale | NA | |
| Striped Dolphin | NA | |
| True's Beaked Whale | NA | |
| Killer Whale | NA in the project area[4] | |
| Long-Finned Pilot Whale | NA | |
| Melon-Headed Whale | NA | |
| Northern Bottlenose Whale | NA | |
| Pygmy Killer Whale | NA | |
| Short-Finned Pilot Whale | NA | |
| Sperm Whale | Endangered (ESA); Depleted (MMPA) | |
| Dwarf Sperm Whale | NA | 200 Hz to 180 kHz |
| Pygmy Sperm Whale | NA | |

None of the species listed in Table 9 have a maximum hearing frequency between 40 and 50 kHz – that is, the use of the 40 kHz echo sounder will not expose any additional marine mammals to acoustic impacts, compared to the 50 kHz equipment that is specified in the Coast Survey PEA.

[10] *http://www.nmfs.noaa.gov/pr/species/mammals/*

[11] Southall *et al.* 2007 and Parks *et al.* 2007

[12] Distinct Population Segments (DPS) of these species are listed as endangered or threatened under the ESA or are listed as depleted under the MMPA, but these DPSs are not located in or near the project areas.

Coast Survey would observe the BMPs agreed to between Coast Survey and NMFS to reduce the potential impacts to marine mammals and threatened or endangered species from both echo sounder use and vessel strike. Based on the nature of the action and adherence to these BMPs, the impacts of the proposed action on marine mammals is consistent with those impacts presented in the Coast Survey PEA. The Coast Survey PEA concluded that underwater sound associated with hydrographic survey operations may lead to temporary avoidance behavior (acoustic harassment), but is unlikely to injure marine mammals in the long term.

Based on these determinations, Coast Survey has determined that the proposed HSRR projects for *Thomas Jefferson* are within the scope of the 2013 Coast Survey PEA.

### 4.2 ESA, NHPA, and CZMA Compliance for *Thomas Jefferson* HSRR Projects

Coast Survey has complied with the requirements of these laws for HSRR projects by coordinating operations in the Norfolk and Virginia Offshore HSRR areas for the years 2018 to 2022 with the relevant regulatory agencies, as described in Table 10 below.

**Table 10: Environmental Compliance Correspondence for the Southern Chesapeake and Norfolk Canyon HSRR Areas**

| Law | Document | Sent to | Concurrence Received on |
|---|---|---|---|
| ESA (NMFS species) | 2013 Coast Survey PEA | NMFS | April 20, 2013 (Biological Opinion) and May 12, 2017 (Letter of Concurrence for Revised Best Management Practices) |
| ESA (FWS species) | Biological Assessment | FWS | December 21, 2017 |
| NHPA | Section 106 Consultation letter | Virginia SHPO | 30-day comment period elapsed on January 22, 2018; no response received |
| CZMA | Federal Consistency Determination | Virginia Department of Environmental Quality | December 8, 2017 |

Coast Survey has evaluated the nature, timing, extent, and location of the activities proposed by *Thomas Jefferson*, and has determined that these activities fall within the scope of the documents and concurrences mentioned in Table 10 above. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 40 kHz and higher for multibeam and side scan sonar systems) that are addressed in the correspondence with the appropriate regulatory agencies.

Therefore, Coast Survey has determined that these activities are in compliance with the ESA, NHPA, and CZMA.

# *5.0 NOAA Ship Ferdinand Hassler*

OMAO and the Office of Coast Survey propose to conduct testing and calibration of echo sounders on the NOAA Ship *Ferdinand Hassler* from August 13-17, 2018. As with all activities at sea, the date of the proposed action could be affected by poor weather, equipment difficulties, or other unforeseen circumstances.

*Ferdinand Hassler* will leave port from Norfolk, Virginia, and proceed to the HSRR location shown in Figure 8 below.

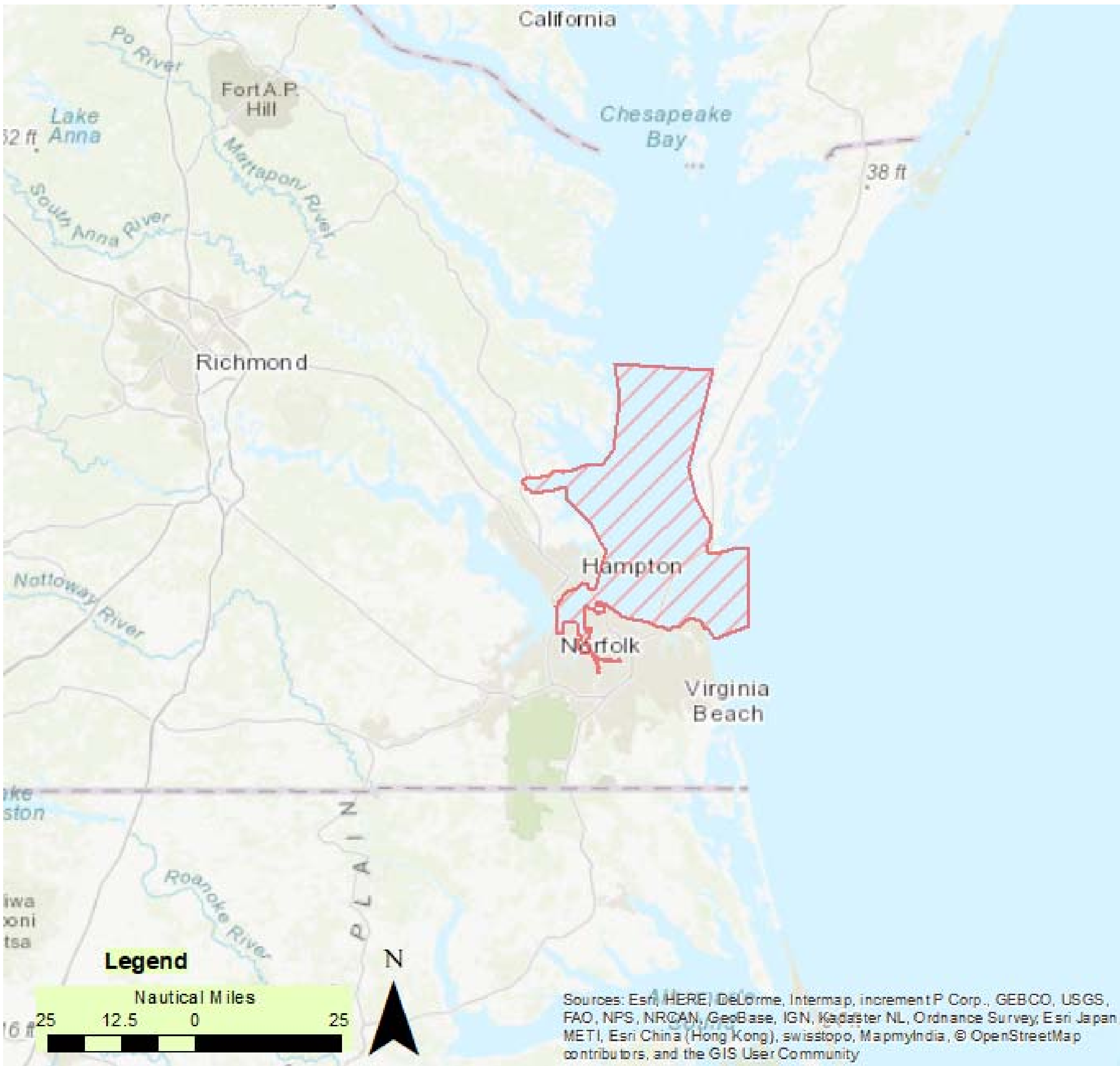


**Figure 8: The testing and training area to be used by *Ferdinand Hassler***

The proposed action will take place only in limited areas within the wider locations shown – Coast Survey will not ensonify the entire delineated area.

*Ferdinand Hassler* will engage in the following activities:

1. Vessel Operation (including launches)
2. Echo Sounder Operation
3. Sound Speed Data Collection
4. Operation of Drop/Towed Cameras and Video Systems
5. Anchoring

The echo sounders to be tested include side scan sonar systems of frequencies as low as 455 kHz, single beam echo sounders at frequencies as low as 24 kHz, and multibeam systems at frequencies as low as 100 kHz.

### 5.1 NEPA Compliance for *Ferdinand Hassler* HSRR Projects

Coast Survey relies on the 2013 Programmatic Environmental Assessment for Coast Survey Operations for compliance with NEPA. All of the proposed activities fall within the scope of this PEA. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 50 kHz and higher for multibeam and side scan sonar systems) that are addressed in the Coast Survey PEA.

Based on these determinations, Coast Survey has determined that the proposed HSRR projects for *Ferdinand Hassler* are within the scope of the 2013 Coast Survey PEA.

### 5.2 ESA, NHPA, and CZMA Compliance for *Ferdinand Hassler* HSRR Projects

Coast Survey has complied with the requirements of these laws for HSRR projects by coordinating operations in the Norfolk and Virginia Offshore HSRR areas for the years 2018 to 2022 with the relevant regulatory agencies, as described in Table 11 below.

**Table 11: Environmental Compliance Correspondence for the Southern Chesapeake HSRR Areas**

| Law | Document | Sent to | Concurrence Received on |
|---|---|---|---|
| ESA (NMFS species) | 2013 Coast Survey PEA | NMFS | April 20, 2013 (Biological Opinion) and May 12, 2017 (Letter of Concurrence for Revised Best Management Practices) |
| ESA (FWS species) | Biological Assessment | FWS | December 21, 2017 |
| NHPA | Section 106 Consultation letter | Virginia SHPO | 30-day comment period elapsed on January 22, 2018; no response received |
| CZMA | Federal Consistency Determination | Virginia Department of Environmental Quality | December 8, 2017 |

Coast Survey has evaluated the nature, timing, extent, and location of the activities proposed by *Ferdinand Hassler*, and has determined that these activities fall within the scope of the documents and concurrences mentioned in Table 11 above. Specifically, the location, nature, and extent of these activities, and their potential effects to the environment, are all within the geographic areas (coastal waters of the United States), types of activities (use of echo sounders, operation of vessels, anchoring, etc.), types of equipment (including echo sounders, sound speed data equipment, etc.), and frequency ranges (10 kHz or higher for single beam echo sounders, 40 kHz and higher for multibeam and side scan sonar systems) that are addressed in the correspondence with the appropriate regulatory agencies.

Therefore, Coast Survey has determined that these activities are in compliance with the ESA, NHPA, and CZMA.

# *Appendix A:*

## *Best Management Practices for Marine Mammals and ESA Species for HSRR Projects*

## INTERIM BEST MANAGEMENT PRACTICES (BMPS) FOR HYDROGRAPHIC SURVEYS

The following BMPs are based on the Endangered Species Act (ESA) mitigation and monitoring measures agreed to between the OCS Hydrographic Surveys Division (HSD) and the NMFS Office of Protected Resources (OPR-ESA) and documented in the April 30, 2013 Biological Opinion[1] and in a May 12, 2017 Letter of Concurrence for revised speed limits.[2] They were adopted in the context of the ESA, but include BMPs for marine mammals listed in the ESA ("depleted" under MMPA). OCS follows these BMPs during all OCS hydro work while MMPA compliance is underway. In all cases BMPs will be communicated to ship and boat crews via project instructions. Contractors will additionally be made aware of BMPs via contract RFPs.

**Vessel Speed Limits**

- Vessels over 65 feet in overall length are limited to a speed of 13 knots or less <u>at all times</u>, unless a slower speed limit applies to the area (e.g., posted speed limits for the protection of manatees).
- Vessels of 65 feet in overall length or less are limited to a speed of 13 knots or less <u>while mapping</u>, unless a slower speed limit applies to the area.

**Echo sounder Restrictions**

- Avoid using sonar frequencies < 180 kHz when possible
  - Suspend **<u>multibeam</u>** sonar transmissions of < 125 kHz, when Southern Resident killer whales or Cook Inlet beluga whale are observed within hearing range (750 yards)
  - If **<u>multibeam</u>** sonar frequencies < 180 kHz must be employed, use echosounders at ≥ 50 kHz frequencies, with the lowest possible power and ping-rate
  - If **<u>single beam</u>** sonar frequencies < 180 kHz must be employed, use echo sounders at ≥ 30 kHz frequencies, with the lowest possible power and ping-rate and a 12° beam angle.
    - If **<u>single beam</u>** sonar frequencies < 30 kHz must be employed, suspend transmissions of 30 kHz or lower when ESA-listed cetacean species (whales, dolphins, and porpoises) are within hearing range (i.e., the 4.2 meter beam width).

**Vessel Maintenance Requirements**

- Meet all EPA Vessel General Permits and Coast Guard requirements
- Use anti-fouling coatings
- Clean hull regularly to remove aquatic nuisance species
- Avoid cleaners with nonylphenols

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[1] http://www.nmfs.noaa.gov/pr/consultation/opinions/biop_ocs_04302013.pdf

[2] *Concurrence Letter on Revised Protective Measures to be Followed during Coast Survey Operations*, NMFS Office of Protected Resources, May 12, 2017

- Rinse anchor with high-powered hose after retrieval

**Anchoring Restrictions**

- Use designated anchorage area when available
- Use mapping data to anchor in mud or sand, to avoid anchoring on corals
- Minimize anchor drag

**Visual Monitoring Requirements**

- Maintain trained observers aboard all vessels; 100% observer coverage
- Make species identification keys (for marine mammals, sea turtles, corals, abalone, and seagrasses) available on all vessels

**Animal Approach Restrictions**

- Avoid nearshore surveys when Steller sea lions are observed onshore
- Avoid approaching within 100 yards of in-water pinnipeds (seals, sea lions, and walruses)
- When possible, suspend single beam sonar transmissions when ESA-listed pinnipeds (seals, sea lions, and walruses) are within hearing range (i.e., within the 4.2 meter beam width).
- Avoid approaching within 200 yards of cetaceans (whales, dolphins, and porpoises), 500 yards for right whales
- Suspend single beam sonar transmissions of 30 kHz or lower when ESA-listed cetaceans (whales, dolphins, and porpoises) are within hearing range (i.e., within the 4.2 meter beam width).
- Avoid approaching within 50 yards of sea turtles

**Vessel Speed Limits**

- As required by 50 CFR 224.105, no vessel of 65 feet or greater in overall length may exceed a speed of 10 knots in designated seasonal management areas for the Right whale.

**Discharge Restrictions**

- Avoid discharge of ballast water and hull cleaning in designated ESA critical habitat

**Anchoring Restrictions**

- Avoid anchoring in abalone habitat (California vessels return to port, rather than anchor) and seagrass ESA critical habitat

**Animal Approach Restrictions**

- Avoid cetacean (whales, dolphins, and porpoises) ESA critical habitat, when possible
- When possible, maintain a vessel distance of at least 3 nautical miles (5.5 km) and a landbased distance of 0.5 miles (0.8 km) of Steller sea lion rookeries listed in 50 CFR 223.202 or Marmot Island

**Bottom Sample Collection Restrictions**

- Avoid collecting bottom samples in seagrass ESA critical habitat

**Tide Gauge Restrictions**

- Avoid installing tertiary tide gauges (i.e., pressure gauge component) throughout the ranges of ESA listed and proposed coral, abalone and seagrass species

**Terrestrial Work Restrictions**

- Do not collect birds (live or dead) or their eggs, nests, or parts (e.g., feathers).
- Take all necessary precautions to prevent wounding any birds or disturbing any bird nests.

## *Appendix B:*

## *ESA and CZMA Concurrence Documents for HSRR Projects – Virginia*

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
*Street address:* 629 East Main Street, Richmond, Virginia 23219
*Mailing address:* P.O. Box 1105, Richmond, Virginia 23218
www.deq.virginia.gov

Molly Joseph Ward
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482

December 8, 2017

Jay Nunenkamp
Environmental Compliance Coordinator
NOAA Office of Coast Survey
1315 East-West Highway
Room 6215
Silver Spring, MD 20910

RE: Federal Consistency Determination: Proposed Crew Training and Testing of Hydrographic Equipment, Chesapeake Bay and Coastal Virginia Waters, National Oceanic and Atmospheric Administration (DEQ 17-163F)

Dear Mr. Nunenkamp:

The Commonwealth of Virginia has completed its review of the federal consistency determination (FCD) for the above-referenced project. The Department of Environmental Quality (DEQ) is responsible for coordinating Virginia's review of FCDs and responding on behalf of the Commonwealth. This letter is in response to the FCD that was submitted by NOAA and received by DEQ on November 3, 2017. The following agencies participated in this review:

Department of Environmental Quality (DEQ)
Marine Resources Commission (VMRC)
Department of Game and Inland Fisheries (DGIF)
Virginia Institute of Marine Science (VIMS)

## PROJECT DESCRIPTION

The National Oceanic and Atmospheric Administration (NOAA) Office of Coast Survey proposes to conduct crew training and testing of hydrographic equipment in Virginia's coastal waters and the Chesapeake Bay. The Office of Coast Survey performs hydrographic surveys in the U.S. Ocean and coastal waters to provide reliable nautical charts and products for safe navigation of the waters. The purpose of this action is to ensure that NOAA's vessels are equipped with appropriate survey gear, that the equipment is operating correctly, and that the ship and crew are properly trained. The five components of the training and testing activities are: vessel operation; echo sounder operation; sound speed data collection; anchoring; and operation of drop/towed cameras and video systems. Two areas will be utilized for the training and testing activities: the Norfolk Training and Testing Area located in the lower Chesapeake Bay and Virginia Offshore Training and Testing Area off of the coast of the Eastern Shore in the Atlantic Ocean. The training activities would occur over a five-year period from 2018 to 2022 and could take place at any time of the year. No single training/testing event on small boats is expected to last more than five days. Training activities on larger vessels could last as long as two weeks. NOAA has submitted a Federal Consistency Determination that finds the proposed action consistent, to the maximum extent practicable, with the enforceable policies of the Virginia Coastal Zone Management (CZM) Program.

## FEDERAL CONSISTENCY UNDER THE COASTAL ZONE MANAGEMENT ACT

This FCD is submitted pursuant to the federal consistency regulation 15 Code of Federal Regulations Part 930 Subpart C for a federal agency activity. Pursuant to the Coastal Zone Management Act of 1972, as amended, federal activities located inside or outside of Virginia's designated coastal management area that can have reasonably foreseeable effects on coastal resources or coastal uses must, to the maximum extent practicable, be implemented in a manner consistent with the Virginia CZM Program. The Virginia CZM Program consists of a network of programs administered by several agencies. In order to be consistent with the Virginia CZM Program, the project activities must be consistent with the enforceable policies of the Virginia CZM Program and all the applicable permits and approvals listed under the enforceable policies of the Virginia CZM Program must be obtained prior to commencing the project. DEQ coordinates the review of FCDs with agencies administering the enforceable and advisory policies of the Virginia CZM Program.

## PUBLIC PARTICIPATION

In accordance with 15 CFR §930.2, a public notice of this proposed action was published in the DEQ Office of Environmental Impact Review Program Newsletter and on the DEQ website from November 9, 2017 to December 1, 2017. No public comments were received in response to the notice.

## FEDERAL CONSISTENCY CONCURRENCE

The FCD states that the project is consistent with the enforceable policies of the Virginia CZM Program. The reviewing agencies that are responsible for the administration of the enforceable policies generally agree with the FCD. Based on the review of the FCD and the comments submitted by agencies administering the enforceable policies of the Virginia CZM Program, DEQ concurs that the proposed project is consistent with the Virginia CZM Program. NOAA must ensure that this project is operated in accordance with all applicable federal, state and local laws and regulations.

**ANALYSIS OF ENFORCEABLE POLICIES**

The analysis which follows responds to the discussion of the enforceable policies of the Virginia CZM Program that apply to this project and review comments submitted by agencies that administer these enforceable policies.

**1. Fisheries Management.** The FCD (page 7) states that the action will not impact finfish or shellfish. The operation of the vessels will not involve fishing or the use of equipment that could incidentally catch fish or shellfish. The echo sounders operate at frequencies that are well above those perceptible to fish.

**1(a) Agency Jurisdiction.** The fisheries management enforceable policy is administered by the Department of Game and Inland Fisheries (Virginia Code 29.1-100 to 29.1-570) and Virginia Marine Resources Commission (Virginia Code 28.2-200 to 28.2-713) which have management authority for the conservation and enhancement of finfish and shellfish resources in the Commonwealth.

**1(b) Agency Findings.**

**1(b)(i) VMRC**. The VMRC did not comment on fisheries impacts. VMRC has no objections to the findings of the FCD.

**1(b)(ii) DGIF**. The waters in which the testing and training activities are proposed are known to support a number of federal- and state-listed fishes, seas turtles, and sea mammals.

**1(c) DGIF Recommendation.** Closely coordinate with the U.S. Fish and Wildlife Service (FWS) and NOAA National Marine Fisheries Service (NOAA Fisheries) regarding the protection of federally-listed species that are found in the project area. Adhere to any conservation actions or protective recommendations for those species deemed necessary by FWS and/or NOAA Fisheries.

**1(d) Conclusion.** The project is consistent with the fisheries management enforceable policy of the CZM Program.

**2. Subaqueous Lands Management.** The FCD (page 5) states that the only interaction with the sea floor that will occur as a result of the training activities would be from anchoring in designated anchoring areas. No measureable effect on subaqueous lands will occur.

**1(a) Agency Jurisdiction.** The management program for subaqueous lands establishes conditions for granting or denying permits to use state-owned bottomlands based on considerations of potential effects on marine and fisheries resources, tidal wetlands, adjacent or nearby properties, anticipated public and private benefits, and water quality standards established by the Department of Environmental Quality. The program is administered by the Virginia Marine Resources Commission (Virginia Code §28.2-1200 to §28.2-1213).

**1(b) Agency Findings.** VMRC has no objections to the findings of the FCD.

**1(c) Conclusion.** The project is consistent with the subaqueous lands management enforceable policy of the CZM Program.

**REGULATORY AND COORDINATION NEEDS**

**1. NOAA Fisheries and FWS Coordination.** Coordinate with the National Marine Fisheries Service (Emily Menashes, 301-427-8500) and the FWS (Troy Andersen, troy_andersen@fws.gov) to ensure that federal-listed species (fishes, sea turtles, sea mammals) that are found in the project area are protected during the training and testing activities.

Thank you for the opportunity to comment on this FCD. The detailed comments of reviewers are attached. If you have questions, please do not hesitate to call me at (804) 698-4204 or Janine Howard at (804) 698-4299.

Sincerely,

Bettina Rayfield, Manager
Environmental Impact Review and Long Range Priorities Program

Enclosures

ec: Amy Ewing, DGIF
Tony Watkinson, VMRC
Emily Hein, VIMS
Jay Nunenkamp, NOAA

## Howard, Janine (DEQ)

| | |
|---|---|
| **From:** | Ewing, Amy (DGIF) |
| **Sent:** | Tuesday, December 05, 2017 11:49 AM |
| **To:** | Howard, Janine (DEQ) |
| **Subject:** | ESSLog# 38724_17-163F_DGIF_AME20171205 |

The waters in with the proposed activities will occur are known to support a number of federally and state-listed fishes, sea turtles, and sea mammals. We recommend close coordination with USFWS and NOAA Fisheries regarding protection of such species associated with the proposed training and testing activities, and adherence to conservation actions or protective recommendations for those species made by them.

The majority of the Virginia's waters impacted by the proposed activities are marine in nature. However, for those activities occurring in inland waters, we find this project consistent with the Fisheries Enforceable Policies of the CZMA.

Thanks, Amy


**Amy M. Ewing**

*Environmental Services Biologist/FWIS Program Manager*

*Chair, Team WILD (Work, Innovate, Lead and Develop)*

*804-367-2211* www.dgif.virginia.gov


*"That land is a community is the basic concept of ecology, but that land is to be loved and respected is an extension of ethics"* **Aldo Leopold, 1948**

VIRGINIA DGIF DEPARTMENT OF GAME & INLAND FISHERIES
CONSERVE. CONNECT. PROTECT.

## Howard, Janine (DEQ)

**From:** Watkinson, Tony (MRC)
**Sent:** Tuesday, November 07, 2017 3:11 PM
**To:** Howard, Janine (DEQ)
**Cc:** Fulcher, Valerie (DEQ)
**Subject:** RE: NEW PROJECT NOAA Office of Coast Survey 17-163F

Janine,

The Virginia Marine Resources Commission has no objection to the findings of the Consistency Determination.

Tony

Tony Watkinson
Chief, Habitat Management Division
Virginia Marine Resources Commission

**From:** Fulcher, Valerie (DEQ)
**Sent:** Tuesday, November 7, 2017 12:04 PM
**To:** dgif-ESS Projects (DGIF) <ESSProjects@dgif.virginia.gov>; Watkinson, Tony (MRC) <Tony.Watkinson@mrc.virginia.gov>; Emily A. Hein <eahein@vims.edu>
**Cc:** Howard, Janine (DEQ) <Janine.Howard@deq.virginia.gov>
**Subject:** NEW PROJECT NOAA Office of Coast Survey 17-163F

**Good afternoon - this is a new OEIR review request/project:**

**Document Type: Federal Consistency Determination**
**Project Sponsor: National Oceanic & Atmospheric Administration**
**Project Title: Office of Coast Survey Crew Training and Hydrographic Equipment Testing**
**Project Number: DEQ #17-163F**

**The document is attached.**

**The due date for comments is DECEMBER 1, 2017. You can send your comments either directly to JANINE HOWARD by email (Janine.Howard@deq.virginia.gov), or you can send your comments by regular interagency/U.S. mail to the Department of Environmental Quality, Office of Environmental Impact Review, 629 E. Main St., 6th Floor, Richmond, VA 23219.**

**If you cannot meet the deadline, please notify the project coordinator prior to the comment due date. Arrangements may be made to extend the deadline for comments if possible. An agency will be considered to have no concerns if comments are not received (or contact is made) within the review period. However, it is important that agencies consistently participate in accordance with Virginia Code Section 10.1-1192.**

**REVIEW INSTRUCTIONS:**

## Howard, Janine (DEQ)

**From:** Emily A. Hein <eahein@vims.edu>
**Sent:** Wednesday, December 06, 2017 1:16 PM
**To:** Howard, Janine (DEQ)
**Subject:** RE: NEW PROJECT NOAA Office of Coast Survey 17-163F

Good afternoon, Janine,

Thank you for checking. We have reviewed the project and have no comments. Typically in the past, we have not communicated if we do not have any comments on a project. Would you prefer that I let you know that is the case?

Best,

Emily

**Emily Hein**
Assistant to the Associate Dean
Office of Research & Advisory Services
eahein@vims.edu, 804-684-7482
VIMS | WILLIAM & MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

---

**From:** Howard, Janine (DEQ) [mailto:Janine.Howard@deq.virginia.gov]
**Sent:** Wednesday, December 06, 2017 9:07 AM
**To:** Emily A. Hein <eahein@vims.edu>
**Subject:** RE: NEW PROJECT NOAA Office of Coast Survey 17-163F

Good Morning, Emily.

I'm getting ready to draft our response for this project so if VIMS has any comments please submit them ASAP.

Thanks,

*Janine Howard*
Environmental Impact Review Coordinator

Office of Environmental Impact Review
Division of Environmental Enhancement
Virginia Department of Environmental Quality
629 E. Main Street
Richmond, VA 23219

t: (804) 698-4299
f: (804) 698-4032

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**From:** Fulcher, Valerie (DEQ)
**Sent:** Tuesday, November 07, 2017 12:04 PM

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401
http://www.fws.gov/chesapeakebay

December 21, 2017

National Oceanic and Atmospheric Admin
1315 East West Highway,
SSMC3
Silver Spring, MD 20910

*RE: Coast Survey Training and Testing – Central Chesapeake Bay*

Dear Jay Nunenkamp:

This responds to your letter, received, November 28, 2017, requesting information on the presence of species which are federally listed or proposed for listing as endangered or threatened within the vicinity of the above referenced project area. We have reviewed the information you enclosed and are providing comments in accordance with section 7 of the Endangered Species Act (87 Stat. 884, as amended; 16 U.S.C. 1531 *et seq.*).

This project as proposed is "not likely to adversely affect" the endangered, threatened, or candidate species listed on your IPaC species list because while the project is within the range of the species, it is unlikely that the species would occur within the project area that was submitted. Therefore, no Biological Assessment or further section 7 Consultation with the U.S. Fish and Wildlife Service is required. Should project plans change, or if additional information on the distribution of listed or proposed species becomes available, this determination may be reconsidered.

This response relates only to federally protected threatened or endangered species under our jurisdiction. For information on the presence of other rare species, you should contact Lori Byrne of the Maryland Wildlife and Heritage Division at (410) 260-8573.

An additional concern of the Service is wetlands protection. Federal and state partners of the Chesapeake Bay Program have adopted an interim goal of no overall net loss of the Chesapeake Bay's remaining wetlands, and the long term goal of increasing the quality and quantity of the Chesapeake Bay's wetlands resource base. Because of this policy and the functions and values wetlands perform, the Service recommends avoiding wetland impacts. All wetlands within the project area should be identified, and if construction in wetlands is proposed, the U.S. Army Corps of Engineers, Baltimore District, should be contacted for permit requirements. They can be reached at (410) 962-3670.

We appreciate the opportunity to provide information relative to fish and wildlife issues, and thank you for your interests in these resources. If you have any questions or need further assistance, please contact Trevor Clark at (410) 573-4527.

Sincerely,

G. La Rouche

Genevieve LaRouche
Supervisor

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
*PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000*
*711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341*

December 1, 2017

Mr. Jay Nunenkamp
Environmental Compliance Coordinator
NOAA Office of Coast Survey
315 East West Highway, SSMC3
Silver Spring, Maryland 20910

**Re: Federal Consistency – Proposed Training and Hydrographic Testing 2018-2022**

Dear Mr. Nunenkamp:

The Department of Ecology, Shorelands and Environmental Assistance Program received your letter regarding the proposed training of crews and hydrographic testing in the Puget Sound to take place from 2018-2022.

Upon review of the letter dated November 3, 2017, Ecology agrees with your determination that the proposed actions are consistent to the maximum extent practicable with the applicable enforceable policies of Washington's Coastal Zone Management Program and will not result in any significant impacts to the State's coastal resources.

If you have any questions regarding this letter please contact Erin Hanlon Brown at (360) 407-6415.

Sincerely,

Brenden McFarland
Section Manager
Environmental Review and Transportation Section
Shorelands and Environmental Assistance Program

## *Appendix C:*

## *ESA and CZMA Concurrence Documents for HSRR Projects – Washington*

cc: Reading file
Glenn Smith/RO via email
Mark McCollough/MEFO via email
Steve Sinkevich/LIFO via email

ES: SvonOettingen:12-7-17:603-227-6418

# United States Department of the Interior

FISH AND WILDLIFE SERVICE

Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503


JAN 3 1 2018

In Reply Refer To:
**01EWFW00-2018-I-0318**

Jay Nunenkamp
Environmental Compliance Coordinator
NOAA Office of Coast Survey
1315 East West Highway, SSMC3
Silver Spring, Maryland 20910

Dear Mr. Nunenkamp:

Subject: Training of Crews and Testing of Hydrographic Equipment off the Washington Coast

This letter is in response to your December 5, 2017, request for informal consultation on the above-named project in the marine waters off the coast of Washington and in Puget Sound. The U.S. Fish and Wildlife Service received your letter with a biological assessment on December 5, 2017. Your letter requested our concurrence with "may affect, not likely to adversely affect" determinations for marbled murrelet (*Brachyramphus marmoratus*) and short-tailed albatross (*Phoebastria albatrus*). This informal consultation has been completed in accordance with section 7(a)(2) of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

The NOAA Office of Coast Survey proposes to perform testing and training of the hydrographic equipment and crews that are needed for surveys to inform reliable navigational charts and other products for safe navigation. The proposed testing and training action will take place during the years 2018 through 2022. Testing and training includes operating vessels (i.e., ships, smaller boats, and remotely operated vehicles), echo sounder operation, sound speed data collection, anchoring, and operation of drop/towed cameras and video systems. Specifically, testing and training will occur in the Astoria Canyon Area (approximately 13.5 nautical miles west of the Columbia River mouth), the Juan de Fuca Canyon Area (approximately 24 nautical miles west of the Olympic Peninsula), and in Puget Sound near Seattle.

Marbled murrelets may be present in any of the testing and training areas, and short-tailed albatross may be present in the Astoria Canyon and Juan de Fuca areas. The vessels will be moving at slow speeds with crew trained to avoid wildlife, we don't expect any part of the proposed action to attract seabirds to the vessels, and both marbled murrelets and short-tailed albatrosses are highly mobile and able to avoid vessels. We therefore expect that a vessel or equipment from vessels (devices used for sound speed data collection, cameras/video systems, or anchors) striking a marbled murrelet or short-tailed albatross is extremely unlikely to occur (discountable). We also expect that disturbance from vessels will be brief and intermittent and that the behavioral responses of marbled murrelets or short-tailed albatrosses will be insignificant.

Marbled murrelets and short-tailed albatrosses may be exposed to sound from echo sounders attached to vessels. The lowest frequency of sound produced by echo sounders is higher than the range of sound believed to be heard by marbled murrelets or short-tailed albatrosses. Since we expect the sounds produced by the echo sounders to be inaudible to marbled murrelets or short-tailed albatrosses, the possibility of auditory injury to either species is discountable. There are no studies we are aware of that show non-auditory injury to seabirds from sonar, but even if echo sounder signals are capable of injuring marbled murrelets or short-tailed albatross we expect exposure to either species to be discountable. The sound energy produced by the echo sounders will attenuate in water so that marbled murrelets and short-tailed albatrosses would have to be less than four meters from the echo sounder in order for the sound to approach the non-auditory injury threshold.

Based on the conclusions stated above, we concur with the NOAA's conclusion that the proposed action may affect, but is not likely to adversely affect marbled murrelet or short-tailed albatross.

This action should be reanalyzed if new information reveals effects of the action that may affect listed species or critical habitat in a manner, or to an extent, not considered in this consultation. This action should also be reanalyzed if subsequently modified in a manner that causes an effect to a listed species or critical habitat that was not considered in this consultation, and/or a new species is listed or critical habitat is designated that may be affected by the action.

If you have any questions about this letter or our shared responsibilities under the Endangered Species Act, please contact Lee Corum (lee_corum@fws.gov; 360-753-5835), or Emily Teachout (emily_teachout@fws.gov; 360-753-9583).

Sincerely,

for

Eric V. Rickerson, State Supervisor
Washington Fish and Wildlife Office

## *Appendix D:*

## *ESA and CZMA Concurrence Documents for HSRR Projects - Oregon*

**Jay Nunenkamp - NOAA Federal <jay.nunenkamp@noaa.gov>**

# Looking for a CZMA federal consistency template for Lincoln County

**Ruther, Elizabeth** <elizabeth.j.ruther@state.or.us> Thu, Jan 18, 2018 at 3:40 PM
To: Jay Nunenkamp - NOAA Federal <jay.nunenkamp@noaa.gov>

Hi Jay!

I had the best of intentions to write you a concurrence and then the holidays and the obligatory illnesses happened and now we are 2 ish days away from the presumed date…..so my apologies! I think a presumed concurrence is fine at this point.

**Elizabeth Ruther** | Coastal State-Federal Relations Coordinator

Oregon Coastal Management Program

Oregon Dept. of Land Conservation and Development

635 Capitol Street NE, Suite 150 | Salem, OR 97301-2540

Direct: (503) 934-0029 | Cell: (971) 239-9460 | Main: (503) 373-0050

elizabeth.j.ruther@state.or.us | www.oregon.gov/LCD

**From:** Jay Nunenkamp - NOAA Federal [mailto:jay.nunenkamp@noaa.gov]
**Sent:** Thursday, January 18, 2018 12:38 PM

[Quoted text hidden]

[Quoted text hidden]

# United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oregon Fish and Wildlife Office
2600 SE 98th Avenue, Suite 100
Portland, Oregon 97266
Phone: (503) 231-6179 FAX: (503) 231-6195

Reply To: 01EOFW00-2018-I-0187
File Name: NOAA Hydrographic Equipment Oregon Coast 01162018.doc
TAILS: 01EOFW00-2018-I-0187
TS Number: 18-183

JAN 18 2018

Jay Nunenkamp
Environmental Compliance Coordinator
NOAA Office of Coast Survey
1315 East West Highway, SSMC3
Silver Spring, Maryland 20910

Subject: Endangered Species Act Section 7 determination for the proposed training of crews and testing of hydrographic equipment off the Oregon coast, 2018 to 2022 (USFWS Number: 01EOFW00-2018-I-0187).

Dear Mr. Nunenkamp,

The Fish and Wildlife Service has reviewed your December 4, 2017, letter requesting informal consultation and the accompanying biological assessment for the proposed training of crews and testing of hydrographic equipment off the Oregon coast (proposed project). The National Oceanic and Atmospheric Administration (NOAA) has determined that the proposed project "may affect, and is not likely to adversely affect" the marbled murrelet (*Brachyramphus marmoratus*) and the short-tailed albatross (*Phoebastria albatrus*). Our review and comments regarding these determinations are provided pursuant to section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*).

As noted in NOAA's biological assessment, NOAA's Office of Coast Survey performs hydrographic surveys in United States ocean and coastal waters to provide reliable nautical charts and other products necessary for safe navigation. The navigational charts prepared with this survey data help prevent mariners from running ships aground or hitting dangerous obstructions, and are used by all ships moving people and products in and out of United States ports. To ensure that the hydrographic fleet can continue this critical service to the country, NOAA must ensure that its vessels are equipped with the appropriate survey gear, that the gear is operating correctly, and that ship and boat crews are trained to perform their duties safely and efficiently.

NOAA's biological assessment states there are four components to the training and testing activities for hydrographic vessels.

1. Vessel Operation – Vessels used by NOAA for hydrographic projects range from small boats to large research ships. In addition to manned vessels, NOAA uses Remotely

Operated Vehicles (ROVs) and unmanned systems to carry and operate scientific instruments. ROVs are operated remotely by a human operator; often tethered to a manned vessel. Unmanned systems operate with various levels of autonomy. These systems use a variety of propulsion sources, including diesel, diesel/electric, battery, solar, buoyancy driven, and wave-gliding propulsion systems.

2. Echo Sounder Operation – Echo sounders attached to a manned vessel, ROV, or an unmanned system are one of the most common categories of active acoustics used in ocean navigation, remote sensing, and ocean and habitat mapping. Echo sounders typically transmit repeated series of short sound pulses (on the order of milliseconds) into the water column. These pulses continue until they reach an object of a different acoustic impedance (typically the seafloor) and reflect back to the echo sounder's receiver. By measuring the time it takes for the sound to return from the seafloor, the depth of the water can be determined. Acoustic systems tested as a part of NOAA's hydrographic program include both single beam and multibeam systems.
3. Sound Speed Data Collection – Sound speed data is collected throughout the survey to determine the speed of sound in the water column at a given location and time, which allows crews to correct for refraction errors in the echo sounder data. Sound speed data would be collected periodically in one of two ways. In the first method, every one to four hours a survey technician slowly lowers a sound speed profiler from a stationary vessel to the seafloor and back. A second method involves a moving vessel profiler; this entails automatically lowering and raising it through the water column at regular intervals while the vessel is in motion. One instrument used for these profiles measures conductivity, temperature, and depth (CTD). Passive collection of conductivity, temperature, and depth with CTD systems involve remote sampling of these parameters that are used in oceanographic sampling and to inform site-specific sound propagation models. CTDs do not produce or measure sound, but instead measure environmental conditions that can be used to reconstruct how sound propagates through the water column. Other instruments used to measure the sound speed profile directly measure the sound speed using high frequency sounding across a small, precisely known gap.
4. Operation of Drop/Towed Cameras and Video Systems – Drop/towed camera deployments are used to ensure that parts of the vessel located below the water line are operating correctly. Drop/towed cameras are launched from the ship or small boats and lowered on a cable using a power winch or by hand using a line.

The two locations off the Oregon coast that NOAA considers suitable for the hydrographic training and testing activities have been identified as Astoria Canyon and Yaquina River. The Astoria Canyon (approximately 13.5 nautical miles from shore) training and testing area covers approximately 1,150 square nautical miles and the Yaquina River area covers approximately 50 square nautical miles. The activities would be performed over the next five years (2018 to 2022), and could take place at any time of the year. No single testing or training event on small boats would be expected to last more than five days. On larger ships, these activities could take longer, but would not be expected to require more than a total of two weeks for any one platform over the course of any single year.

NOAA vessels would operate at relatively low speeds and would move in straight, predictable transects. Marine mammal observers will be present on all Coast Survey vessels at all times, and crews are trained to be aware of and avoid all wildlife. Crews on Coast Survey projects will be provided with visual aids allowing them to identify marbled murrelets, and will not approach marbled murrelets that are on the water. Coast Survey will employ a variety of multibeam echo sounders during the project, ranging as low as 40 kHz.

Based upon the information we know about marbled murrelets preferred use of nearshore waters (within 3 miles in Oregon of shore and 5 miles in Washington), the foraging habits of the short-tailed albatross, the described use of the echo sounders and the frequency levels employed during use, and the use of trained wildlife observers during operations, we concur with your determination that the proposed action "may affect but is not likely to adversely affect" the marbled murrelet and short-tailed albatross.

This concludes informal consultation pursuant to section 7(a)(2) of the Endangered Species Act. If information reveals effects of the action may affect listed species or critical habitat in a manner or to an extent not considered in this consultation; the action is subsequently modified in a manner that causes an effect to listed species or critical habitat that was not considered in this consultation; and/or, new species is listed or critical habitat is proposed that may be affected by this action, NOAA would need to re-initiate consultation.

If you have any further questions regarding this project please contact Jeff Dillon of my staff at (503) 231-6179.

Sincerely,

Craig Rowland

for Paul Henson, Ph.D.
State Supervisor